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Recent Technological Developments in Fisheries: Pre and Post Harvest Operations

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on

Recent Technological Developments in Fisheries: Pre and Post Harvest Operations

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Venue: ICAR-CIFT, Cochin, Kerala

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FOREWORD

Globally, fishery sector is gaining policy attention owing to its potential for providing food and nutrition for the small farm holders, in addition to its livelihood implications for large-scale fisher communities. The sector has established its dominance in the socio-economic growth of many developing economies by providing opportunities for income and employment generation across the value chain. The efficiency of the fisheries value chain depends largely on development of sustainable and economically viable technologies. Integrating the outcome of R&D activities through extension and technology commercialization is another important area of concern.

ICAR-CIFT, since its inception, has been involved in research and extension in the realm of harvest and post-harvest fisheries sector. Technologies and protocols have been developed for traditional and mechanized harvesting sectors to promote sustainable fisheries. In addition, array of products like value added foods from fish and fishery products, nutraceutical products from fish and other marine resources, proteins from fish waste, by-products of industrial and culinary value etc. have been developed. Business incubation facility in the institute facilitates prospective entrepreneurs to commercialize the technologies generated by ICAR-CIFT for initiating business ventures across the value chain. Further, the developments in the sector require cross learning and application of innovations at different stages starting from tide to table in various part of the world.

I am happy to note that after a gap of almost two years of Covid-19 restrictions all over the globe, ICAR-CIFT has received this opportunity of conducting the international training programme on *"Recent Developments in Fisheries; Pre and Post-harvest Operations"* during 12-19 December, 2022 in offline mode; sponsored by African Asian Rural Development Organization (AARDO), New Delhi. I hope such type of programme would create more avenues for technology dissemination, popularization and commercialization among the AARDO-partnered countries.

This 'Training Manual' comprising of all the lecture notes; outlines the concepts, issues, scopes and opportunities of various technologies in the domain of harvest and post-harvest fisheries. I hope this publication will be useful for numerous stakeholders in the sector to devise appropriate strategies to enhance sectoral development. Lastly, I congratulate the scholarly efforts of the coordinators, co-coordinators and resource scientists to bring out this valuable publication in time.

Dr. George Ninan
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Fish for Fighting Malnutrition

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Though it is bitter to accept, nutrient deficient diets are a fact of everyday life for hundreds of children. 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, the risk of death from common childhood illness, or result in life-long increase health consequences. Current approaches to address malnutrition in children have serious limitations. Exclusive breastfeeding meets nutritional needs until six months of age, and beyond that, young children need 40 essential nutrients to grow and be healthy. Interestingly, fish is probably the most cheapest to provide all the 40 essential nutrients a young child needs to grow and be healthy. Fish especially seafood is an excellent resource for proteins, vitamins, trace elements and polyunsaturated fat (omega-3 fatty acids). The details about the importance of seafood in lowering the risk of malnutrition are relatively scanty.

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. It is very much interesting to observe that big eyes of tuna are very much rich in EPA and DHA, which constitute around 70-75% of total PUFA. EPA and DHA are very much essential for the development of brain and heart tissue. EPA and DHA play a major role in maintaining health of the young children by modulating the lipid metabolism. These ω-3 fatty acids also regulate prostaglandin metabolism, which regulates the vascular functions in growing children. They also have influence on kidney function by modulating the retention of water and removal of excess sodium, which plays a major role in the behavior of kids. DHA is critical to normal eye and vision development in the early and later parts of the human beings. Along with linoleic acid it makes > 1/3rd of FA in human brain and retina. DHA also increases memory power of young children. A person can expect good health if he or she consumes 0.5-1g of PUFA/day.

High content of highly digestible protein, amino acids viz available lysine, methionine and cysteine and minerals makes fish protein a highly nutritious product. Fish contain all the essential amino acids in required proportion and hence have a high nutritional value. The non-protein amino acid taurine is present in rich quantities in seafood. Histidine content is high in proteins of mackerel. Fish proteins lessen the risk of microalbuminuria in young children. Fish protein powder can be used to formulate infant foods, soups and protein containing beverages to enhance their protein content & nutritive value. It can be very well considered as milk replacer. Fish proteins can be incorporated as a protein supplement in children diet. 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. Collagen is found in skeleton, fins,

skin and air bladder (source of pure collagen) of fish. Collagen powder is a very good source of all amino acids required for the synthesis of extra cellular matrix protein of connective tissue in young children. Its supplementation is also beneficial in the normal functioning of fragile bone joints, which is essential in the case of athletic young children. Supplementation of chitosan prepared from shell fish exoskeleton supplementation helps to overcome lactose intolerance in young children by influencing the microflora associated with gut. On hydrolysis of chitin (exoskeleton of crustaceans) with concentrated acids under drastic conditions gives relatively pure amino sugar D-glucosamine. It is essentially required for the construction of cartilage - the tough connective tissue that cushions the joints in young children. Glucosamine stimulates the production of glycosaminoglycans (the key structural components of cartilage) as well as the incorporation of sulfur into cartilage. Glucosamine is effective for easing osteo pain, aiding in the rehabilitation of cartilage, renewing synovial fluid, and repairing joints, which are very much common occurrences in young growing children.

Fish meat is a good source of B vitamins (red meat > white meat). Fish liver, eggs, milt and skin are good sources of B1, riboflavin, pyridoxine, folic acid, biotin and B12- Hence, fish intake is capable of preventing various anemias in young children. Fatty or semi fatty fishes are excellent sources of vitamin D. Anti-hemorrhage factor Vitamin-K is also present in fish. In fish flesh Vitamin E occurs as α-tocopherol, a potent antioxidant vitamin involved in counteraction of free radical mediated oxidative damage to the cell membranes. Large quantity of vitamin E (500-3000) is present in liver and body oils. Hepatic reserves of Vitamin A is much greater in fish compared to mammals and birds. Liver oils from shark and Tuna are rich in Vitamin A & D.

Fish and shellfish are valuable sources of Ca & P, also contains Fe, Cu, Se. Calcium powder from back bone of tuna can be used to combat calcium deficiency in diet, particularly of children. Calcium deficiency can lead to bone failure and spine curvature in children. Salt water fish have high content of iodine-good for brain function. Sodium content is low – makes it suitable for low sodium diets. Tuna are sources of macro mineral Mg, which contributes to hardness of bone and acts as co factor for certain enzymes important in nerve & muscle function. Tuna is also an important source of essential antioxidant trace element Se -provides protection against heavy metal poisonings & 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.

Squalene, an isoprenoid molecule present in fish liver oils, is capable of carrying oxygen at the cellular level, causing further improvement in organ function through cellular metabolism. In today's polluted environment, lack of exercise and poor lifestyle, it may be a potential source of oxygen for young children. It also helps to regulate the menstrual cycle and improves irregular and abnormal cycles in teenage female children. Squalene can be used as an immunoprotector in children. It also acts as relaxant, giving added vigor and vitality

without the hyper-activity associated with other food supplements, generates hair and smoothens skin.

Unfortunately, most current food aid programs for developing countries, especially in India rely almost exclusively on the fortified cereal blend of corn and soy that may relieve a young child's hunger, but does not provide proper nourishment. Programs that respect the minimal nutritional needs of infants and young children, and work with countries most affected by the crisis to put access to nutrient-rich foods at the center of their efforts to tackle childhood malnutrition have to be adopted vigorously. Definitely promoting fish as health food alleviates early childhood malnutrition. It has to be done through direct nutrition programs that ensure infants and young children from even the poorest families. Marine organisms are potential sources of variety of compounds with nutraceutical applications to reduce malnutrition. Yet there is little has been explored in this aspect. Further researches have to be carried out to utilize the fishery resources for fighting malnutrition in young children.

Recent advancement in fish harvest sector by ICAR-CIFT

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Introduction

With about 171 million tonnes of fish production which peaked at in 2016 globally, aquaculture contributed around 80.3 million tonnes and 90.9 million tonnes through the total capture production (FAO, 2018). Worldwide 59.6 million people engaged fisheries and aquaculture in 2006, out of that 19.3 million people engaged in aquaculture and 40.3 million people engaged in fisheries. In India fisheries sector is promises 14 million employment and income generation. Fishing has been an ancient occupation. It directly contributes approximately 10% of the total animal protein intake by humans. As far as per capita consumption is concerned, global fish consumption is growing at an average rate of about 1.5 percent per year. It was 9.0 kg in 1961 which touched 20.2 kg in 2015. Preliminary estimates for 2016 and 2017 pointed to further growth to about 20.3 and 20.5 kg, respectively (FAO, 2018). India is one of major fish producing countries in the world. It has an Exclusive Economic Zone (EEZ) of 2.02 million sq.km, a long coastline of 8,118 km and two major groups of Islands with rich and diverse marine living resources. The marine fisheries wealth is estimated to have the annual harvestable potential of 4.412 million metric tonnes. In the year 2017-18 the marine fish landings of India was 3.83 million tonnes which is 5.6% more than the preceding year (CMFRI, 2018). There were 1,99,141 fishing vessels operates in marine fisheries sector of India out of which mechanised, motorised and traditional artisanal vessels contributes about 36.5%, 36.9% and 26.6% respectively. Among the mechanized crafts fully owned by fishermen, 29% were trawlers, 43% were gillneters and 19% were dolnetters (CMFRI, 2012b). Where as in terms of total catch landed during year 2017- 18, mechanized, motorized and artisanal contributed around 75%, 23% and 2% respectively (CMFRI, 2012b, 2015, 2018). Indian marine fisheries resource supports the livelihood of about 4 million people. The increased demand for fish has prompted the development of new harvesting techniques mainly fuel-efficient and resources specific craft and gear and responsible fishing techniques. The recent developments in fish harvesting techniques are briefly reviewed in this chapter. The ICAR-Central Institute of Fisheries Technology (ICAR-CIFT) set up in 1957 is the national institute in the country where research related to fishing and fish processing is undertaken. The institute started functioning at Cochin in 1957. As a contribution to the nation's fishing sector, ICAR-CIFT focuses on basic, strategic and applied research in developing fuel efficient fishing vessels, responsible fishing gears, designing innovative implements & machinery for fishing, Eco-friendly technologies for responsible fishing and low-energy fishing technologies for the traditional sector. This institute has also been in the forefront of recommending standards for netting, netting yarn and netting twine used for fishing net and standardization of fishing gear accessories.

Contributions of ICAR-CIFT in Fish Harvest Sector

Fuel efficient fishing vessels 19.75 m fuel efficient multipurpose fishing vessel; Sagar Harita

The fishing vessel, Sagar Harita, a 19.75 m long fuel efficient multipurpose fishing vessel designed by Fishing Technology Division of ICAR-CIFT and built by Goa Shipyard Limited (GSL). The vessel has met all the requirements of the Indian register of shipping (IRS) and ICAR-CIFT. This new generation energy efficient green fishing vessel is equipped with the latest technology solar panels, aiming to promote green energy and reduce the carbon foot prints. The solar panels fitted on the vessel cater the energy requirement for navigational lights, cabin lights etc. The vessel also incorporates an optimized hull design with a bulbous bow, fuel efficient propeller design and improved sea keeping characteristics. Modern tools and techniques including software simulation and model testing have been used for the refinement of the design. The ship's super structure above deck level has been made from FRP using the latest 'resin infusion technology' thereby significantly enhancing the sea keeping performance.

15.5 m deep sea fishing vessel; Sagar Kripa

ICAR-CIFT has taken initiative to develop fuel efficient fishing vessels in view of high expenditure incurred in mechanised fishing operations. A 15.5 m multi-purpose deep sea fishing vessel Sagar Kripa with steel hull was designed and developed with energy saving features. These include optimized hull design, optimized installed engine power, fuel efficient propeller and propeller nozzle. The commercial trials by the fishing boat operators have saved about 17% of the fuel cost.

Energy saving trawling technologies

Trawling is an active fishing method in which a bag shaped fishing gear is towed from mechanized fishing vessel. It is known to be one of the most energy intensive fishing methods.

Low drag trawls

In excess of 60% of the total resistance in the trawl system is known to be contributed by netting alone. Fuel consumption during trawling is directly related to the drag of the gear system. Substitution of large meshes in the front trawl sections has been reported to reduce the drag of the trawl system by about 7% and hence reduces fuel consumption in trawling. The reduced drag permits greater trawling speed and/or operation of larger trawl with the available installed engine power. Large mesh demersal trawls, have been extensively adopted by mechanized fishermen of north-west coast, Mangalore and Kerala, for resources like Ribbonfish, Squid, Horse Mackerel, Mackerel and Pomfrets, due to its low drag and fuel efficiency. Fuel cost alone constitute up to 75% of operational expenditure. Drag offered by trawl depends on factors like design and rigging of the net alone contributed 58% of the total drag offered by a trawl. Estimation of drag of commercial trawls in Kerala reveal that it ranges from 1.5 to 49.0 kN according to the design used. Adoption of optimised towing speed, thinner

twines and large mesh to reduce twine surface area are found to bring down the drag and hence the fuel consumption. Conventional trawls made of HDPE are with more drag due more twine surface area and weight of webbing. Ultra High Molecular Weight Polyethylene is a stronger material compared to HDPE, which permit to use thinner twine for trawl fabrication. Trials of 24 m UHMWPE low drag trawl developed by ICAR-ICAR-CIFT revealed that average reduction of drag was 15% with 13% average reduction in fuel consumption and average 7.5% reduction in operational expenditure compared to HDPE trawls.

Cambered otter boards:

Otter boards are known to contribute 20-25 % of the total drag of the trawl system. Introducing camber in otter board design is known to reduce resistance of the boards considerably, by increasing the hydrodynamic efficiency of the boards. ICAR-CIFT has introduced high aspect ratio, cambered otter boards for semi-pelagic trawling. Introduction of camber in otter boards reduces the drag of the trawl system by 4% with accompanying savings in fuel.

V-form otter boards:

The V-form otter boards are hydrodynamically efficient and have very inherent stability. It is made of steel and do not utilize wood in their constructions. These boards do not plough or dig into the bottom and will tide over smaller bottom obstacles, thus becoming suitable for trawling in uneven and rocky grounds. V-form boards are cheaper and safe in shooting and hauling if properly rigged with a longer service life of 5-6 years. V-form type otter boards have become popular among trawler fishermen of southern India and Gujarat, since its introduction.

Eco friendly trawls for off bottom resources:

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. ICAR-CIFT off bottom Trawl System (ICAR-CIFT OBTS) 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 facilitates harvesting of fast swimming demersal and semi-pelagic finfishes and cephalopods, which are mostly beyond the reach of conventional bottom trawls, currently used in commercial trawl fisheries in India.

Low energy and eco-friendly harvest technologies for the inland fisheries and traditional marine sector

Appropriate craft designs and improved gear designs such as optimised gill nets, lines and traps have been developed and introduced for the inland fisheries. Improved and durable lobster traps with escape window for juveniles have been developed as substitute for traditional traps of short life span and low efficiency, for harvesting of spiny lobster. The rich

tuna resources of the Lakshadweep waters are under-exploited as the fishing operations are still limited to traditional pole and line method. ICAR-CIFT has introduced large mesh gillnets and monolines (monofilament long lines) in Lakshadweep waters, for targeted fishing of Tunas, Billfishes, Seerfishes, Carangids and Perches, in an effort to diversify fishing methods and improve catching efficiency.

Large mesh purse seine and power block for purse seine operations

Purse seining is one of the most efficient and advanced commercial fishing methods. It is aimed mainly at catching dense, mobile school of pelagic fish and includes all elements of searching, hunting and capture. Introduction of large mesh purse seines facilitated by ICARCIFT has led to the revival of small mechanized purse seine fishery in Kerala. The changeover of mesh size in the purse seine from the conventional 20 mm to 45 mm has shown good results and the purse seiners has been able to land larger size classes of high value species. The traditional fishermen and the purse seiners were targeting small pelagic like anchovies, sardines and small mackerels in the coastal waters. The purse seiners were also targeting the same resource in the coastal waters. There was severe competition and rifts between the tradition and mechanized purse seiners. With the introduction of large mesh purse seine, the fishermen could go to deeper and farther waters targeting large pelagic like tunas, seer fish, pomfrets and large mackerels thus reducing the competition and fishing pressure in the coastal watersExperimental fishing operations carried out from the purse seiner Bharat Darshan during the period 2007-10 in the depth range of 50 to 220 m revealed that the catch mainly comprised of large sized mackerels (62%), followed by tunas (16%), carangids (14%), miscellaneous fishes (6%) and pomfrets (2%). All the mechanised purse seiners based at the Cochin Fisheries harbour, Kerala have changed over to 45 mm mesh size purse seines and started operations in the deeper waters targeting skipjack tuna, little tunnies, carangids, black pomfrets, horse mackerels, barracudas, seerfish and mackerel.

Bycatch Reduction Devices (BRDs) for responsible fishing and sustainable resources

BRDs for trawls

Among the different types of fishing, trawling accounts for the highest rate of bycatch along with the target species. Almost 70-90% of the trawl catch is bycatch, among which, about 40% is constituted by juveniles that are invariably discarded resulting in two serious consequences- depletion of the resources and pollution of the marine water and the consequential threat to the ecosystem. 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; only its quantities vary according to the type of the gear and its operation. Therefore, one of the important research focuses of the Fishing Technology Division was development of bycatch reduction devices. Bycatch reduction device (BRD) is a device aimed at reducing the catch of non-targeted and unwanted species of fish in shrimp trawling. While BRD is a broad term used to describe any device that can be employed to eliminate or reduce the bycatch, turtle excluder device (TED), though in principle a BRD, is a specialized form of BRD designed to eliminate turtles, sharks and rays also from the trawl. These devices have

been designed and developed taking into consideration the differential size and behaviour pattern of shrimp and fish inside the net. BRDs include Fisheye which is stainless steel escape chute attached in the codend for the escape of actively swimming finfishes and rigid grid devices; and soft BRDs such as square mesh windows, Bigeye, Sieve net and International Award winning design Juvenile Excluder cum Shrimp Sorting Device (JFE-SSD) which have been evaluated and recommended for use in Indian waters. Sea turtles are endangered species. Various protection measures have been adopted the world over, including India, for its protection. ICAR-CIFT has developed an indigenous design of the turtle excluder device which is appropriate for the Indian conditions. ICAR-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 ICAR-CIFT, great care has been taken to ensure 100% escapement of the turtles while escapement of fish and shrimp at the minimum possible level

Low-cost substitutes for conventional craft materials

Traditionally, wood is used for construction of fishing vessels in India which has become scarce and costlier. Focused attention has been given in identifying alternate materials for fishing vessel construction, in order to reduce the dependence on traditional scarce wood species. Cheaper and readily available cultivated wood species with short life cycle such as rubber wood, fortified with dual preservative treatment using 7.5% ASCU and creosote, has been identified for construction of canoes operated in backwater and coastal fisheries. A number of preservative treated rubber wood canoes have been distributed for field operations by fishermen groups and cooperatives. The cost of the canoe is 35 – 40% less than a canoe of same size built of 'Anjili', the usually used wood. This saves the depleting forest wealth, helps the rubber farmer to get a better price for his underutilized wood and gives a durable, maintenance free boat at affordable cost to the poor fisherman especially of the South West and North East where rubber trees are grown. Designs of fiberglass crafts have been developed for operation in inland waters. Fibreglass sheathing as protection against borer attack and biodeterioaration and as preventive against environmental pollution while using preservative treated wood in boat construction has been popularized, in traditional sector. Use of Aluminium alloy for construction of inland and coastal fishing craft has been demonstrated. Durability, light weight, corrosion resistance, toughness and resilience, low maintenance and high re-sale value make aluminum alloy a good material for construction of fishing craft.

Treated Rubber Wood Canoe

Central Institute of Fisheries Technology has evolved a simple technology for development of traditional fishing canoe from the rubber wood, which comes as a waste from rubber plantations. Though rubber wood is comparable to many structural timbers in terms of mechanical properties and working qualities, it is highly perishable under marine conditions. The study proved rubber wood as suitable for construction of canoe after upgrading by chemical preservative treatment. The conventional prime quality boat building timbers are very scarce and have become very costly. Traditional fishermen using wooden canoe find it

extremely difficult to afford the cost. The new technology can reduce construction cost of small canoes by 35-40%.

FRP-Sheathed Rubber Wood Canoe

ICAR-Central Institute of Fisheries Technology has developed a fibre glass reinforced plastic (FRP) sheathed rubber wood canoe for operation in marine and inland waters. The rubber wood, which comes as a waste from rubber plantations is upgraded through chemical preservative treatment and the canoe made using the treated wood is further given a sheathing of FRP. The technology has made possible the utilization of rubber wood and also provided additional dimensional stability through sheathing. The FRP sheathing provides water proofing, reduces maintenance, resistance to impact and abrasion and prevents attack of marine borers and other decay causing organisms besides giving an extended service life and better appearance for the wooden canoe. Canoe made of treated rubber wood and sheathed with FRP will give a maintenance free service life of 15-20 years.

ICAR-CIFT Collapsible Fish Trap

ICAR-CIFT improved the design of traditional trap as collapsible fish trap (1 m×0.6 m×0.6m) with two rectangular and square frames with stainless steel. HDPE webbing of 80 mm mesh size is used as cover of the trap to allow fish to enter. Two entrance funnels made of plastic mesh are fixed on both sides. These traps were supplied to local fishermen and experimental trials were conducted along backwaters of Vypeen Island, Kumbalangi, Cheranellor and Varapuzha. Etroplus suratensis, Lutjanus argentimaculatus, Lates calcarifer, Epinephelus sp, Scylla serrata are the common target species and the trap can be set and hauled after 2-3 days of soaking. Average catch/haul is 1.5 kg. Design of the trap is simple and any fishermen can adopt the technology and is 40% lighter in weight and durability is 3- 4 times more than the conventional traps. Cost of ICAR-CIFT collapsible fish trap is only 50% of the conventional bamboo traps with same dimension. ICAR-CIFT collapsible fish trap will be a better option for the traditional fishermen to improve the livelihood.

Myctophid trawl (28.4 m & 45 m)

Myctophids are the most abundant group of mesopelagic fishes in the Indian Ocean. About 137 species of myctophids are reported in the Indian Ocean. About 75% of total global catch of mesopelagic fishes is accounted by myctophids. Two mesopelagic trawls (28.4 m and 45 m) with four equal panels were designed and operated from FORV Sagar Sampada and ICAR-CIFT research vessel R.V. Matsyakumari-II. Estimated trawl drag for 45 m trawl in terms of towing speeds of 2to 3kn range from 4.9 to 7.3 t. The new mid-water trawl system designed to attain largermouth area, smoothly tapering trawl body with small meshes in belly and codend, which can be towed at about 2.5 kn is adjudged to be appropriate, taking into consideration available information on biological characteristics and behavior of myctophids, fishing conditions and vessel characteristics.

ICAR-CIFT Off-bottom Trawl System (OBTS)

Trawler fishermen in India cannot depend on shrimp and associated species alone for viable commercial operations any more, and there is need to adopt responsible alternate trawl systems for harvesting large demersal and semi-pelagic species. ICAR-CIFT 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 200 kg 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. ICAR-CIFT OBTS has been developed and perfected after extensive field trials and observations, using acoustic gear monitoring instrumentation and inference from statistical evaluation of catch, over an extended period.

Nano Cerium oxide, Titanium oxide & Iron oxide coating for corrosion resistance in boat building steel.

BIS 2062 carbon steel is extensively used for fishing boat construction and is highly susceptible for corrosion in the hull, welding joints and coating failures under marine environments. This technology demonstrates the application of novel multifunctional nano metal oxide mixtures comprised of iron, titanium and cerium as marine coating to prevent corrosion. The electrochemical performance of nano metal oxide mixture coatings, applied over boat building steel, was evaluated inNaCl medium. The thin film surface coatings showed an efficient corrosion resistance with increased polarization resistance and low corrosion current density. The electrochemical impedance spectral data exhibited the improvement in the polarization resistance of outermost surface and internal layers. The coating responded faster recovery to normal state when subjected to an induced stress over the coating. The nano material in the coating behaves as a semiconductor; this enhanced electronic activity over the surface of the steel. The photo oxidation behavior of Fe2O3 and TiO2, deter the microbial attack

Biofouling resistant polyethylene cage aquaculture nettings: A new approach using polyaniline and nano copper oxide

Biofouling in aquaculture cage nets causes occlusion of mesh openings, thereby increasing weight and drag, deformation of cages due to the ensuing stress, reduction of volume, thereby decreased stocking density per area, anoxic condition due to disruption of dissolved oxygen flow, blocking of food waste diffusion, restriction of water exchange, increased hydrodynamic force, all of which adversely impacted fish health. It has been reported that removal of fouling from a cage net costs 25% of the total project budget. Cages are fabricated mainly with high density netting whose non polar nature makes incorporation of antifouling biocides difficult. The surface of polyethylene needs to be modified to develop strategies against fouling. The novel approach employed by ICAR-CIFT was to synthesise a coating of polar or conducting molecule over non-polar polyethylene to incorporate antifouling biocides thereby rendering protection to protect the polyethylene aquaculture cage nets from biofouling.

Use of advanced fish finding and navigation techniques

Recent advances in technology have provided fishermen with equipment to reach the potential fishing ground accurately (Global Positioning Systems), detect the presence of fish acoustically (echosounder and sonar), thus saving the search time and fishing time and hence saving energy. These advances in technology have been popularized among fishermen, in collaboration with agencies like MPEDA and Department of Fisheries, for bringing down fuel use and environmental impact through fuel use. This, coupled with affordability and subsidy support, has resulted in significant penetration of GPS and Echosounder among small mechanized commercial fishermen, all along the coast.

Fishing craft and gear materials

Various cost effective protective measures against bio deterioration of wooden fishing vessels have been developed and are in use. Use of low cost timber like rubber and coconut have also been experimented successfully for small canoes. In India, ICAR-CIFT which plays a major role in the development of harvest technologies has also developed aluminium alloy sheathing for wooden fishing vessels, cathodic protection against marine corrosion in fishing boats, new substitutes for propeller material for cost savings, marine anti-corrosive paints, marine antifouling paints, chemical wood preservatives, indigenous resin based protective coatings for wooden crafts, ferrocement for boat building, rubber wood canoes, fibreglass reinforced plastic coated fishing canoes. Primarily, mechanized boats were using local gear. Major advances in fibre technology, along with the introduction of modern gear materials, have directly influenced and brought about important changes in the design, dimensions and method of handling fishing gears. Extensive use of synthetic materials like PA, PE and PP have perceived in 1960s which created a revolution in fabrication of fishing gears. Today, the entire fisheries sector uses only synthetic fibers for gears. Twisted netting yarns and braided netting yarns of different sizes are available in the country. Combination rope of Polyethylene and Polypropylene (Danline) and Polyamide monofilament is being extensively used as an import substitute for tuna and shark longlines. The development of combination wire rope as an import substitute for deep-sea fishing is a recent innovation which has now been commercialised. ICAR-CIFT has standardised specifications for the use of polypropylene multifilament netting yarn with lower specific gravity and better tenacity than nylon (Silas, 2003; Meenakumari, 2011).

Conclusion

In recent years, the developments in harvest technologies in fisheries sector have taken place rapidly. ICAR-Central Institute of Fisheries Technology has contributed greatly to the revolution of fishing industry as well as technology diffusion programmes in a very significant way in the fisheries sector across India. While the fisheries sector is facing challenges in terms of excess capacity of fleet, diminution of fish resources and degradation of the fisheries environment in the coastal waters. The under-utilised and resources in the deeper waters hold potential along with rapid expansion envisaged. It's very imperative to have appropriate technology for application of resource conservation in the shelf waters under an appropriate

management plan and diversification of fishing to unconventional resources such as mesopelagics, oceanic cephalopods and large pelagics in the deeper waters. Minimisation of harvest and post-harvest losses, development of technologies for reducing carbon and ecological footprints in the harvest sectors are areas which need focussed attention. Today fisheries sector is watched by many as a sunrise sector as it helps in alleviating food security as well as supports many auxiliary sectors. ICAR-CIFT has major contributions for this transformation. Over the years institute has carried out research on harvest and post-harvest aspects of fish extensively based on the sectors need and developed many ready-to-transfer technologies. Notable ones in harvest sector include design and construction of fishing vessels, eco-friendly fishing gear, satellite-based imaging systems to locate fishing grounds, and automated fish hauling systems. The research information generated is transferred to the end users by adopting suitable extension methodologies.

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Energy saving Fishing Vessel for green fishing

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Introduction

According to FAO, 2016 the total number of fishing vessels in the world in 2014 - 4.6 million. 64 % of reported fishing vessels were engine-powered. The fishing fleet in Asia was the largest, consisting of 3.5 million vessels and accounting for 75% of the global fleet, followed by Africa (15%) Latin America and the Caribbean (6%) North America (2%) and Europe (2%).

Design and construction of fishing vessels

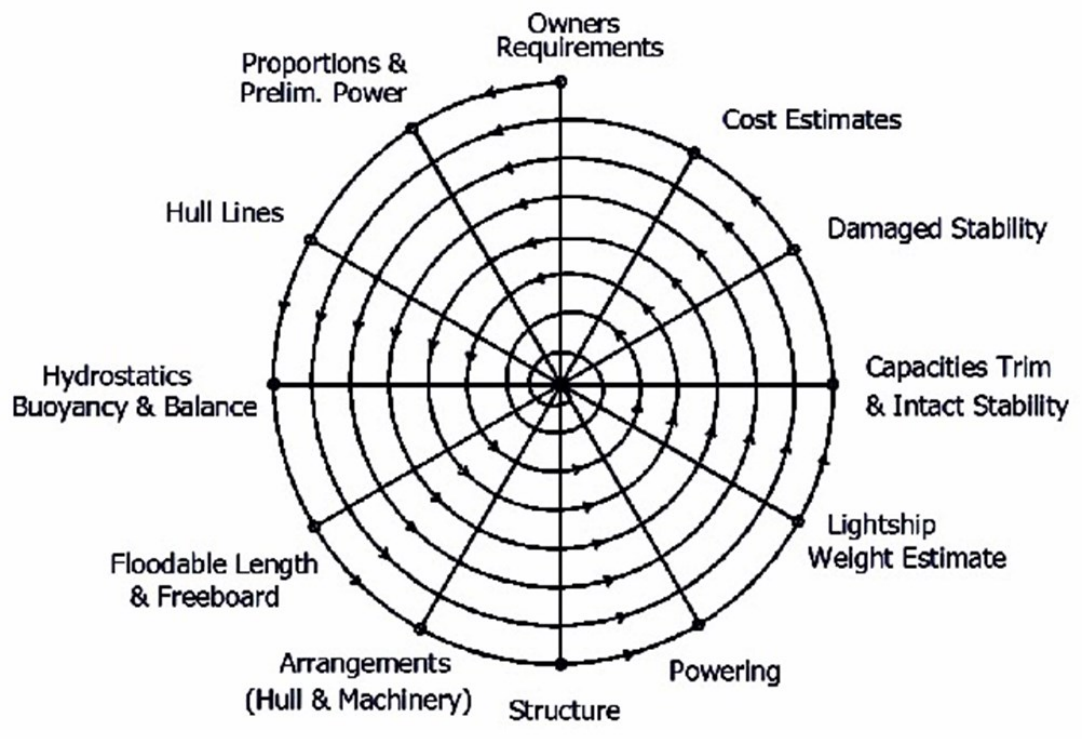
The sea going boats and ships are designed and constructed based on the rules of the classification societies and the registering authorities of the flag nation. This ensures the structural and operational safety of the vessel as well as the crew, cargo and other items onboard. Class or National Standard organisation approved raw materials only shall be used for the construction. Main engine, valves and other machinery ate to be approved type. Design of fishing vessel plays a vital role in fuel efficiency. Optimization of hull forms is the most effective and logical way to reduce the drag force for increasing fuel efficiency and the result is minimal carbon emission and considerable saving in expenditure of fishing operations.

Types of fishing vessels

The most common commercial fishing vessels are trawler, gillnetters, Liners, seiners and combination fishing vessels. Trawlers include stern trawlers, side trawlers, factory trawlers and pair trawlers. Liners consist of hand liners, long liners and pole and liners. Seiners are purse seiners and ring seiners. There are also dredgers, pot and trap vessels, trollers, mother vessels, carriers, factory vessels, fishery training vessels and fishery research vessels.

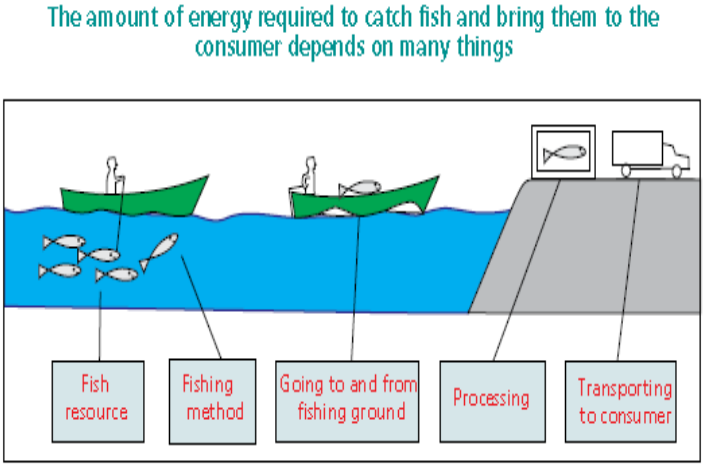
Design of fishing vessels

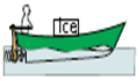
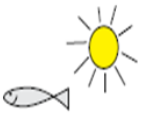
The commercial fishing vessels, are to be designed and constructed based on standard ship building procedure. Design starts from the owners requirements. Then the preliminary lines plan, offset table, hydrostatic particulars, structural drawings and resistance calculation are done. The structural design is carried out based on class rules. The preliminary stability analysis is carried out during this design stage. Finally the cost is estimated. The design stages will have to be refined at any of the above stages for excess of cost, resistance or any other reasons. So it becomes an iterative design. This method is called design spiral as given below.



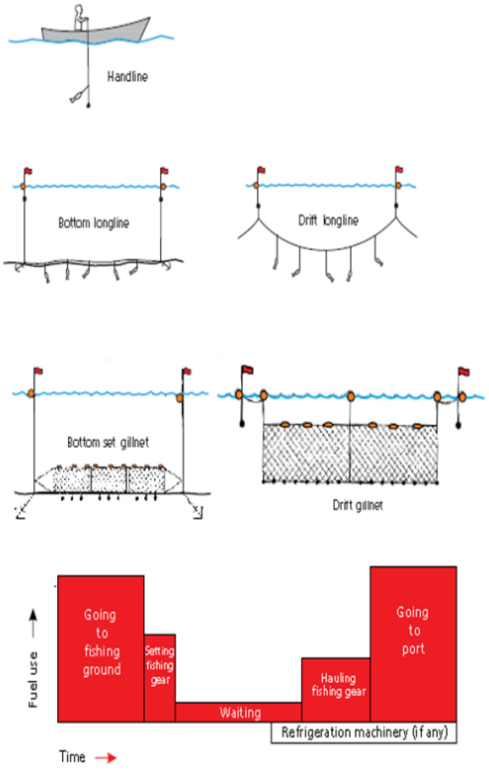
Energy use in fisheries

Energy is required to reach the fishing ground, carry out fishing and return to the harbor. This is shown as below.

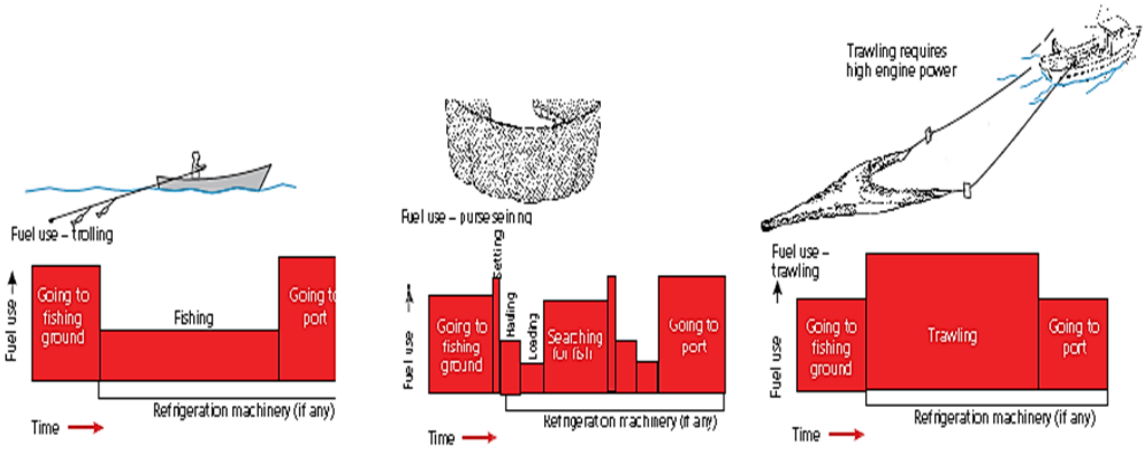


	Pre-industrial methods Human and solar energy	Industrial methods Fuel energy 100–3000 litres of diesel per tonne
Going to and from fishing grounds	 Human power or wind	 Engine power
Hauling fishing gear	 Human power	 Mechanical hauler
Processing	 Sun drying, smoking and salting	 Icing or freezing
Transporting to consumers	 Human, animal power or boat	 Truck, train, boat or plane

There are two fishing methods such as passive and active fishing methods.



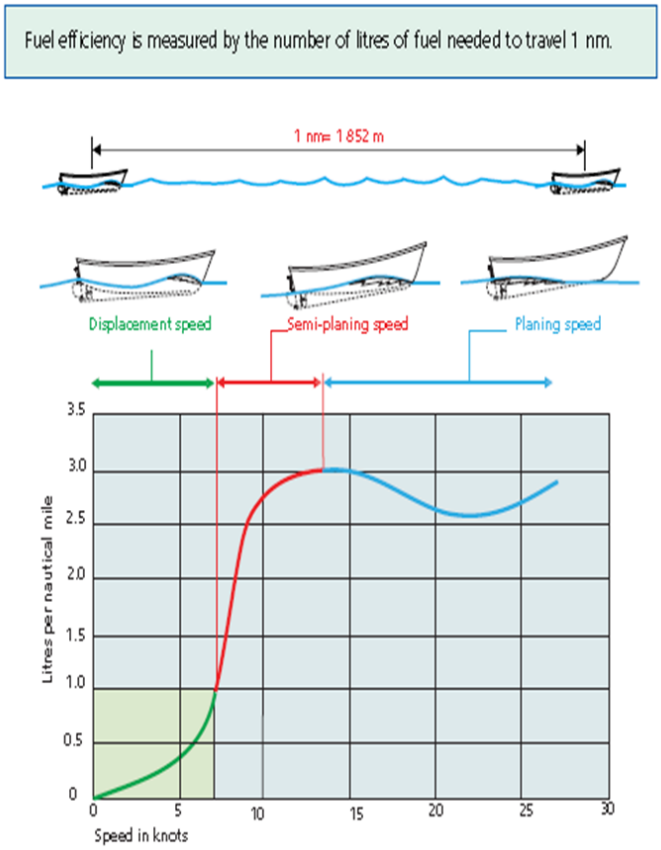
Passive fishing



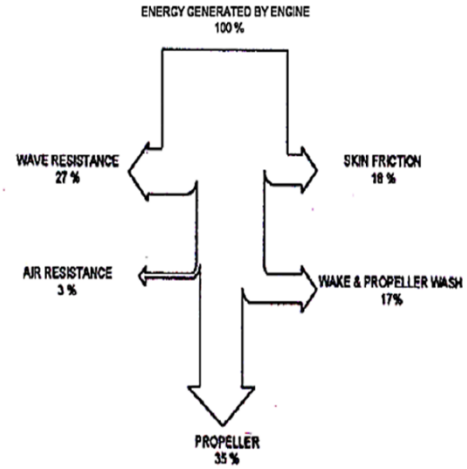
The above are active fishing methods.

Trolling	Purse seining	Trawling
Fuel is used both for travelling and for fishing	Most fuel is used going to and from fishing grounds and searching for fish	Most fuel is used to drag the trawl along the bottom (bottom trawling) or above the bottom (pelagic trawling). Reducing power going to and from fishing grounds saves fuel

The main energy consumption is in the burning of fuel. This depends on the type of fishing vessel hull, the speed of operation and endurance as explained below. Trawling consumes 0.8 kg of fuel while longlining and gillnetting consumes between 0.15 and 0.25 kg of fuel and purse seining requires 0.07 kg of fuel, to catch one kilogram of fish. (Gulbrandson ,1986). Trawling consumes nearly 5 times more fuel compared to passive fishing methods such as longlining and gillnetting and over 11 times more fuel compared to purse seining for every kilogram of fish produced. The gear resistance therefore has a large effect up on overall fuel economy.



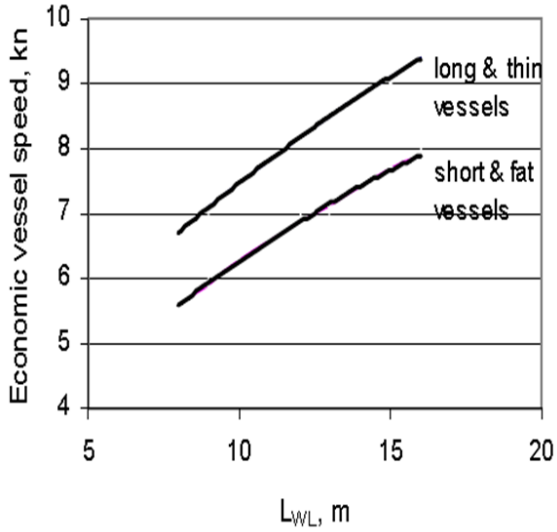
Energy losses in a small trawler when not dragging are indicated in Figure below.



Energy efficiency can be achieved by designing fuel efficient hull form, making efficient propulsion system, optimum size of vessel, setting optimum speed of operation, following operational control for fuel efficiency, combination fishing in one vessel, energy efficient fuel, making bulbous bow for fuel economy, minimise the energy loss from the engine: reduction gear shaft, propeller and appendages and using ecofriendly materials for construction. An efficient propulsion system can be achieved by selecting a proper main engine power and rpm, reduction gear ratio, shaft diameter, length of shaft and making a Kort nozzle for trawling. Optimum size of vessel means the main dimensions are to be fixed for the maximum

utilisation of space and minimising the waste. The Length Over All, Breadth, and Depth and Draft are to optimum. Optimumising fish hold volume, space for engine room, accommodation and wheel house helps in fuel conservation. Over speed will attract higher fuel consumption and operational expense. Also lead to more maintenance on engine, gear box and higher level of pollution. Minimising unnecessary idling at harbour and sea, unnecessary use of generator, fans, lights, etc will improve fuel efficiency. Keeping log book and making entry to know the daily fuel consumption will help in knowing the fuel use.

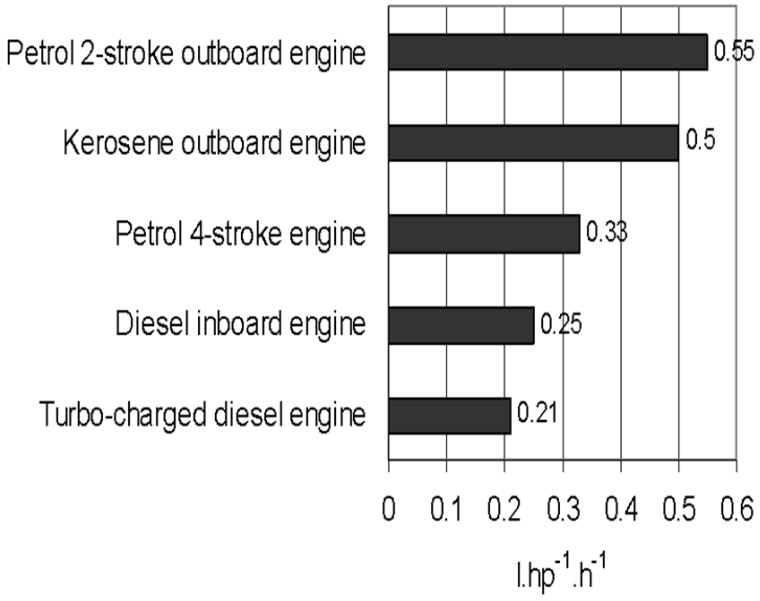
The power required to propel a vessel is mainly a function of (i) speed, (ii) length of water line and (iii) displacement. Vessel speed is the single most important factor affecting fuel consumption of the vessel. The fuel consumption drastically increases as the vessel approaches maximum speeds, due to great increase in wave breaking resistance. It has been shown 35 to 61% savings in fuel is possible for a reduction of 10-20% speed (The Oilfish project-Nordforsk, 1981-84; Gulbrandson, 1986; Aegisson & Endal, 1993). Economic vessel speed is the most important practical measure among fuel saving practices. The choice of operating speed, particularly while cruising to the fishing ground and back, is generally under direct control of the skipper of the vessel. Economic speed is shown below.



Reduction in power requirements can be achieved by (i) increasing length of water line (LWL) and (ii) reducing displacement wherever possible at the design stage, and (iii) by taking measures for control of hull fouling. For normal economic speed the ratio between the vessel speed (kn) and the vessel length (ft), $V/\sqrt{L}$ is close to unity.

By increasing length of waterline while keeping the other dimensions same, it is possible to reduce the hull resistance and increase the speed. Increase in construction cost has to be balanced against fuel saving advantages. Trials in Norway, Denmark and India have indicated 15 to 20% reduction in hull resistance by modifications with bulbous bow.Reduction in displacement also contributes to lower fuel consumption. Hull built of aluminium, FRP and plywood will be lighter than that of steel, ferro cement and conventional wood construction. 23% reduction in fuel is reported for a 12.5% reduction in weight of small vessels. Fuel saving advantages in such cases has to be balanced against a possible reduction in stability, sea

kindliness and cost of the vessel. Fuel consumption due to fouling could increase by 7 percent at the end of first month 44 percent at the six months and 88 percent at the end of 12 months (Gulbrandson, 1986). Hence periodic hull cleaning and application of antifouling paints can lead to considerable savings in fuel. The fuel consumed by different types of engines arte explained below.



Disadvantage of outboard is high propeller speed and consequent low propeller efficiency. Advantages are low cost and portability. Turbo-charged diesel engines are about 15% more fuel efficient than normally aspirated engines. Petrol 4-stroke outboard engines, which have a much better fuel economy and emission standards, are also being introduced in small-scale fisheries. Direct fuel injection (DFI) petrol outboard engines which is reported to have still better fuel efficiency, are expected to be introduced in small-scale fisheries. Modern marine diesel engines will run most economically at a service speed of 80 percent of the maximum continuous rating of the engine. The propeller design and size should be so selected as to allow the engine to operate in the area of lowest specific fuel consumption.

Right sizing the installed engine power

Smaller engines have multiple benefits of lower investment cost, lesser maintenance and huge reduction in the fuel consumption. Overpowering the vessel is wasteful in terms of energy as the maximum attainable speed of the vessel is dependent on length of the waterline. The installed engine power for a small fishing vessel engaged in passive fishing methods like gillnetting and lining, need not exceed 5-6 hp per tonne of displacement with a 10% increase in the tropical conditions (Gulbrandson, 1988). In the case of outboard engines, this should be 7.5 to 9 hp per tonne of displacement. A 3% reduction in engine RPM is reported to reduce fuel consumption by 10% and 11% reduction in RPM reduce fuel consumption by 30%.

Bulbous bow to reduce resistance

Use of Bulbous bow has been experimented during the design of deep sea fishing vessel and found to be successful. F.V.Sagar Harita deep sea gill netter cum Long liner is designed and constructed with bulbous bow as shown below.

Energy efficient fuel

Fuel form the major recurring input in fishing and is dependent on factors related to engine and size of vessel (Baiju & Boopendranath, 2014). The least polluting and cheap fuel for the vessel propulsion is wind power using sail. Before the 19th century almost every ship had been using only the wind power by classic sails, and supporting the worldwide trades and logistics in those days. In 1980's after the last oil crises, many kind of modern sail-assisted ships were developed. Now, they will be hoped to become one of the best solution against the increasing CO2 discharge. Fishing vessels in many parts of the world are using sails in the small scale fishery. Advantages are no fuel burnt and hence no pollution. The operational cost very low, no maintenance of engine gear box, etc and no battery/storage of power. The cost is minimum and successful in traditional sector.

Fuel cell, Nuclear are also less polluting but very expensive. LNG has been successfully experimented in marine vessel propulsion. Diesel engines produce high thrust are the most widely used fuel in this sector.

LNG+ Diesel vessel

For small scale fishing petrol engines are utilised. A combination of kerosene and petrol in outboard engines are also popular in some countries. Diesel and petrol engines produce high pollution.

Solar power for fishing

Solar power being naturally available helps reducing the use of fossil fuel in the fishing vessel operation. There is no atmospheric pollution from solar boats. The noise level is also very low. The below picture shows the solar boat developed for inland fishing.

Materials of vessel construction

The popular materials used in the construction of boats and ships are woo, steel, Aluminium, Fiberglass reinforcement plastic and ferro cement. Among these wood utilizes least energy and is the most efficient material. But availability and maintenance of wood is a practical problem. Steel is the most popular material has been used worldwide for ships and deep sea fishing vessels. This is corrosive in the marine environment and requires high care and maintenance. FRP is suitable for small vessels especially beach landing type fishing vessels due to its lightweight. Ferro cement has not become popular due to its weight and manufacturing difficulties.

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Principles of Fishing Gear Design and Importance of Fish Behaviour Studies for Gear Improvement

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The choice of fishing gear and its design is determined by the biological, behavioural, and distribution features of the target species. There is no such thing as universal fishing that is suited for all fishing situations and resources. Fishing gear must be chosen or developed with the greatest number of features appropriate for the specific fishing condition and resource in mind, and trade-offs may be required.

The scale of operations, the size and engine power of the fishing vessel, energy conservation objectives, selectivity, and resource conservation objectives, catch volume requirements, operational and handling requirements of the gear, prevailing weather conditions, skill required for fabrication, maintenance and operation, material availability, local traditions, and economic considerations will all influence the choice of fishing gear and its design features.

The primary mechanisms used in fish capture are (i) filtering, such as in trawls, seines, and traps; (ii) tangling, used in gill nets, entangling nets, and trammel nets; (iii) hooking, in hand line, long line, and jigging; (iv) trapping, used in pots and pound nets; and (v) pumping, such as fish pumps. The main behaviour controls utilised in the fish capture process are (i) attraction, by using bait, light, and shelter, and (ii) repulsion or avoidance reaction, used for herding or guiding by netting panels in set nets and trawls or sweeps.

Though the primary mechanism is non-specific, the design considerations for the gear, would require information that is specific to the targeted species and the mechanical properties of the structure/material that is used for capture. Body size and shape dictates the mesh size necessary to enmesh and hold the fish in gill nets, as well as the mesh size required to keep the desired size groups of the species in trawls, seines, and traps without gilling. This is also linked to the tensile strength requirements for netting twine in gill nets, as well as hook size and lines in hook and line. Again, body size is directly linked to swimming speed. Swimming speed is directly related to body size, which is an important factor to consider while fishing with towed gear.

To direct finfish into trawl codend, big mesh trawls and rope trawls utilize the principle of herding, in which front trawl sections are replaced by very large meshes or ropes to decrease drag. The otter boards, wires, and sweeps, as well as the sand-mud cloud formed by the boards on finfishes in between the boards, are used to boost the capture rate by extending the effective sweep area.

The vertical aperture of the trawl mouth, the vertical dimension of gill nets, and the catenary of the main line of the long line with branch lines and hooks all align with the vertical range of the layer of highest fish abundance, maximising catching efficiency. As a result, information regarding the vertical distribution of the species is essential to improve the

horizontal and vertical dimensions of gill net netting panels, long line catenary, and trawl mouth arrangement.

Large-scale changes have occurred in the design, fabrication, operation, and catching capacity of modern fishing gears such as trawls, purse seines, and long lines due to the development and wider availability of synthetic gear materials, recent advances in vessel technology, navigational electronics, gear handling machinery, fish detection methods, and fish behaviour studies. Traditional fishing gear such as entangling nets, hooks and lines, and traps have all benefited from design improvements and increased efficiency in recent years.

Fishing gears evolved by trial and error, and until recently, only empirical methodologies rather than analytical procedures were employed to estimate design parameters. However, in recent decades, there have been design and development initiatives based on fish behaviour, engineering studies, system analysis, and model studies that incorporate resource conservation, ecological, and economic challenges. The general principles involved in development of a gear design is as below (Fig. 1):

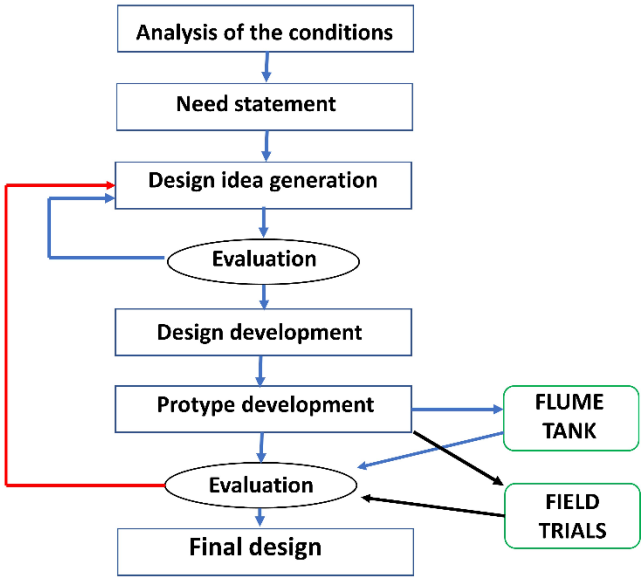

Fig. 1. Key factors involved in the designing process of a gear

A paradigm change in fishing philosophy has occurred, owing to the alarming pace of decrease of key fish species and, secondarily, greater knowledge of fishing's habitat and ecosystem implications. As a result of the changes in the fishing industry over the last decade, the focus of fishing technology research is now on conservation and development of fishing gears and methods that have the least negative impact on fish stocks, habitats, and the environment.

Selective fishing with fishing gear that has the least impact on non-target organisms and other biota would be required for sustainable capture fisheries. This will need a thorough understanding of the behaviour of both targeted and non-targeted species. As a result,

understanding fish behaviour in relation to fishing gear is a prerequisite for designing, building, and operating environmentally responsible fishing gear. There are only a few studies with clear results on the behaviour reaction to fishing stimuli, and the problem of multi-species fishing further confounds the issue of selective capture in fishing gears. Experiments to understand fish behaviour near fishing gear are limited, owing to the inherent difficulty in capturing and researching behaviour in actual field settings, as well as the high expense of studying fish behaviour near fishing gear, especially for active gears like trawls. There is a considerable amount of work on the development of selective gears, much of which is based on trial-and-error approaches such as experimental fishing and examining species assemblage structure. Gears and other technical devices, on the other hand, are rarely developed with the behavioural ecology of the species or targeted group in mind, and hence are frequently non-selective. The knowledge of the behavioural responses of targeted species to stimuli associated during fishing and its field level application is a relatively new field in the Indian scenario.

The importance of fish behaviour in understanding and improving size and species selectivity for sustainable harvest of resource has encouraged applied fish behaviour studies in the context of fish capture. Fishing is a complex process, involving a large number of external and internal factors, however some of the parameters that are critical in the capture process include:

Vision

Understanding visual characteristics of fish is an important component in understanding the fish capture process and interactions between fish and fishing gear. While the structure of the eye is well known and mechanisms of vision have been described for several fish, many commercially important marine species have received little attention. Despite many years of research into the visual systems of fish, detailed knowledge and understanding of the role of fish vision in their reaction to fishing gears during capture processes needs further research.

Most fish species can distinguish colour by the use of red, green, and blue sensitive cones. At least two types of cones are required for colour discrimination, while some freshwater and shallow – living marine species have the capability to detect ultraviolet radiation with a fourth type of cone. Electroretinogram (ERG) is used to monitor the response of retina to stimulation by different wavelengths of light (i.e., color) and to determine spectral sensitivity of fisheyes.

Photosensitivity is the ability of fisheye to receive light and to get visual information in ambient light conditions. Light intensity varies with water depth, time of day, and transparency or turbidity of water. To allows fish to function visually over a wide range of light intensities in the natural environment, functional changes are made by shifting of positions of rods and cone cells in the retina. Different fishing gears provide a different contrast image according to ambient light conditions, gear type, and the visual sensitivity of the fish. The contrast of an object against the water background is more important than the brightness of the object (Wardle, 1993).

A moving image is more important to fish than a static one and detection of movement is dependent on visual acuity and persistence of time – which is the time taken to process the

image by the organism. The flicker fusion frequency (FFF), which is the frequency at which flickering images fuse to produce a continuous image, is dependent on light intensity, temperature, and duration of the flash. Fish can detect motion at a wide range of light intensities from 10-7 to 10-14 lux (Protasov, 1970) and as light intensity increases, the sensitivity to detection of an image is enhanced and decreases with decreasing light.

Behavioural techniques to investigate FFF and visual acuity is by optomotor response, which is the movement of the eyes, head, curvature of the body or trunk, or movement of the entire animal in response to follow a moving image (Sbikin, 1981). Comparative studies have shown that Elasmobranchs and species living in low light conditions have lower FFF, when compared to fishes that live near the surface.

The detection of movement has important implications in how fish reacts to fishing gears, particularly in active systems like trawl gear, where the fish holds station with the gear components like floats, ropes and meshes until it becomes exhausted, by means of herding and optomotor responses.

The visual contrast of the fishing gear against the background is more important that the brightness of the gear underwater. It is understood that there is a complex relationship between colour and contrast of gear components, ambient light intensity and quality of water. In general, it is interpreted that light coloured netting panels are more difficult to detect against a bright background because of low contrast and reverse for materials that strongly contrast with their surroundings, when viewed (Fig. 2).

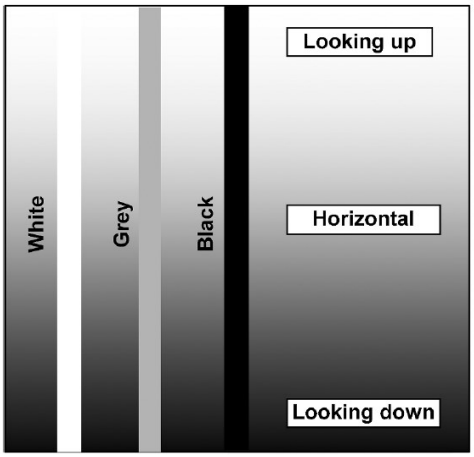

Fig 2. Contrast of white, grey and black twines hung vertically in water in relation to viewing angle (Source: He, 2010)

Swimming speed

Swimming speed is an essential parameter that impacts the species' catchability. Fish have a wide variety of body forms, and swimming is a predictive factor of the organism's body shape. Swimming is an energy-dependent activity; hence it has favourable associations with persistent swimming, which is critical in active swimming gear such as trawls. Quantification of the swimming speed of targeted fishes is a very important metric that can help in designing

the gear and has significant impact on the fuel consumption in an active fishing gear. Swimming involves large expenditure of energy and hence will also affect the quality of harvested fish.

There are two types of swimming noticed in fish: sustained swimming speed and burst swimming. Sustained swimming speed involves regular swimming speeds at constant speeds, whereas burst swimming involves sudden spurts, which often involves very high demand on energy. The energetic cost of swimming is the sum of the resting or standard metabolic rate and the energy required to produce thrust. Expressed in watts (joules per second), it increases as a J-shaped curve with speed in m/s (Fig.3) The exact shape of the curve depends mainly on the species, size, temperature, and condition of the fish. Because of the curve's form, there is only one ideal speed at which the metabolic rate to speed ratio is at its lowest. This ratio reflects the amount of effort required for a fish to cover one metre. To make comparisons, the optimum speed (Uopt), where the amount of energy used per unit distance covered in the minimum, is used as the benchmark. Fish use an average of 0.07J/N to swim their body length at Uopt. Temperature has a significant impact on swimming capacity, both in terms of speed and endurance, with maximal swimming speed doubling for every 10^0 increases in temperature. It is usually difficult to derive this metric in field conditions and research is often conducted in circular tanks (Fig. 4) The Uopt speeds of some commercially important species are shown in Table 1.

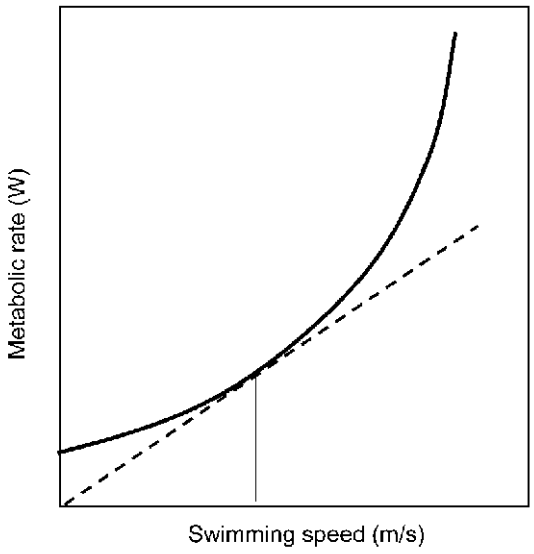

Fig. 3 Theoretical curve of the rate of work as a function of swimming speed. The amount of work per unit distance covered (J/m) is at a minimum at Uopt.

Fig. 4 Moving gantry system installed at ICAR-CIFT for studying swimming speed of fish

Hearing

Sound travels at a speed of about 1500 m/s underwater and it can be used to control fish behaviour over a longer distance compared with chemical or visual stimuli. There are several methods, that use sound in fishing operations to attract fishes. It is recorded that fish schools can be driven into the set-nets by vocal sound of dolphins and yellowtail (*Seriola quinqueradiata*) can be attracted from the deep layers by the swimming and feeding sounds of its conspecifics.

Sound has been used as an active guidance method to transport fish over long distance for transport of fish seedlings to a desired location in sea without physical handing. The studies using sound as an attracting device is mostly being used in aquaculture facilities, where certain amount of conditioning would be required, which would not be easily possible for wild fish, however traditional methods still employ sound for capture.

It has been hypothesised that sound could be an important factor in FAD based fishing, in which the underwater sound generated by the materials, could act as an acoustic sensory cue for fishes to aggregate. It has been understood that the reaction of fish to an approaching vessel follows similar responses of that of a prey fleeing from predator. It has been reported that cod were capable of initiating avoidance response at distances ranging from 470 m to 1470 m from the approaching fishing vessel. The “butterfly pattern” produced in either sides of the vessel, as a result of hull’s ability to shadow propeller cavitation, produce large lobes of high-intensity noise.

Sound is also increasing being used to deter Endangered threatened and Protected (ETP) species form commercial gears, like gillnets and purse seines. Pingers , which produce sounds at frequencies that deter cetaceans are already in market and are effectively being used in different fisheries. Habituation is one problem that is being encountered when these devices and the efficacy is found to decrease with regular use of these deterring devices.

Olfaction

The proportional relevance of sensory modalities varies between species and is determined by prey choices, sensory organ size, brain structure, diel activity cycles, and visual stimuli.

Olfaction as a stimulus is being used increasingly in the long lines and trap fishery world over. Since this capture process depends on the odour plume concentration and its direction, the inherent swimming speed and the activity of the fish also depends on the efficiency of capture. Larger fast swimming species have higher probability of encountering the stimulus. Using dispersion models, it is understood that fish responds to thresholds to bait odour from 10 m to several kilometres, depending on the state of food deprivation, rage of attractant release from the bait and current velocity. Food deprivation is found to have significant effect on the odour tracking ability of fishes, with a study showing increase in attraction of feed deprived sablefish by factor of 57 over that of a fish fed to satiation. Rheotaxis also is an important factor in fishing methods using olfaction as cue, since flow pattern would disorganise the fish that is actively searching for the source of the plume. So, it is suggested that it would be beneficial, to develop artificial baits that would release plumes at a high rate to attract fishes from long distances and then sustained release of plumes to allow the fish to get close to the source.

The attraction towards baits, can also be effectively used for exclusion of non-targeted species like sharks in long lines. An artificial bait using squid liver developed for tuna longlining and tested off the Hawaiian Islands, showed significant reduction in the shark bycatch, with catch rates that were 67% lower than with traditional squid bait (Januma et al., 2003). Other examples of using this technique included reduction in sea turtle bycatch in US Atlantic swordfish fishery, using mackerel baits.

Conclusion

Fishing is a complicated process that involves the fish, the gear, and the environment's related cues, and capture is the consequence of a complex combination of these variables functioning in unison or independently. The key elements that determine fish behaviour reactions are light and vision, sound and hearing, water current and rheotaxis, and temperature. These factors may work individually or concurrently, and it is frequently difficult to "tease apart" the distinct effects. Individual fish reactions to external stimuli, as well as their ability to counteract external influences, further complicate the difficulty of analysing fish responses to stimuli.

In recent years, the main objective of fishing technologists has been to design and develop fishing gear with conservation in mind. As a result, understanding how fish react to various stimuli is crucial to understanding how they are caught in various fishing gears, as well as how this process may be changed to allow undersized and undesirable fish to escape from various fishing gears.

Quantifying the response of fish to all the stimuli is difficult to imitate on field and hence some of the factors (extrinsic/intrinsic) that influence the behaviour of fishes in the capture process can be imitated in the laboratory using suitable techniques.

In fishing technology, studies that link behaviour with fishing gear design are few, yet this is crucial information that may aid in the design and development of responsible fishing gear.

Nano Technology and its Applications In Fisheries

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Introduction

The term nanotechnology was coined by Prof Taniguchi, Japan in 1974 conference of the Japanese Society of Precision Engineering. 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. Prof R. Feynman 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 some *control* of the arrangement of things on a small scale we will get an enormously greater range of possible properties that substances can have, and of different things that we can do ... The problems of chemistry and biology can be greatly helped if our ability to see what we are 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 100nm.

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. It is shaped like a footballs with an empty core. The number of carbon atom in fullerene was ranged from 20 to several hundreds. Simio Lijima 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.

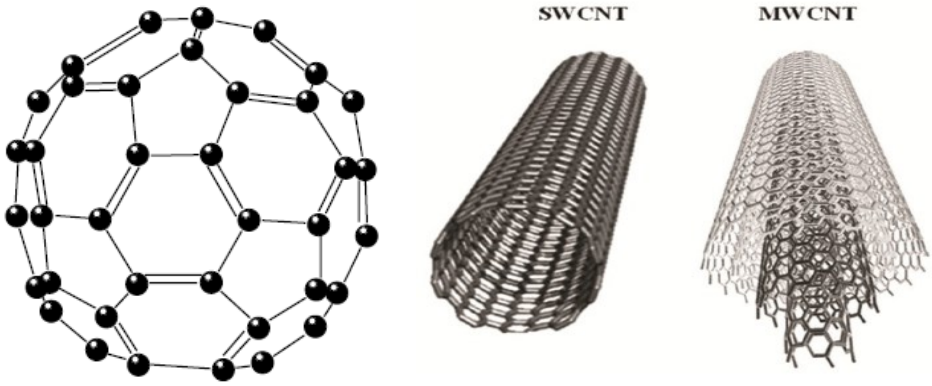

Fig 1. A) Fullerene C60 molecule B) SWCNT and C) MWCNT.

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. 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 – 800ºC. CNTs are formed on the catalysts. 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 ºC 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.

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 1. 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. 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. Applications of nano materials in medicine are like mucosal lining treatment and inflammatory bowel treatment using nano pharmaceuticals.

Food science:
Nano materials were potential to apply as food supplements For example, antioxidant nutrients may be included in nanocomposites, nanoemulsions, nanofibers, nanolaminates and nanofilms, or nanotubes etc.

Research in CIFT

Nano application in aquaculture cage nets

a)Nano copper oxide coated HDPE cage nets

Polyethylene fibres are extensively used to prepare the aquaculture cage nets. Polyethylene is non polar polymeric molecule and difficult to introduce the biocide over the molecule. Generally biocide coatings were made over the cage nets using adhesives. The major disadvantages of biocides like copper oxide coating over the cage net is leaching to the aquatic environment and disposal of nets after use. The major advantage of nano materials as biocide very less quantity used, increased surface area of exposure and exhibit higher efficiency. Since polyethylene is non polar we have undertaken different methodology to make the polyethylene surface polar. The surface was coated with in situ synthesised polyaniline, a conducting polymer. Over this surface nano copper coated and their characteristics were studied. Uniform coating of polyaniline and copper was showed by Scanning electron micrograph and Atomic force micrographs. The formation of the biocide was verified by analysing FTIR spectra. Polyaniline coated polyethylene showed IR absorption was shifted from 1362 to 1396 cm-1 indicating the attachment of polyaniline over PE. Quinanoid peak of NH4+/NH+ in polyaniline was exhibited at 1047/1161 cm-1 and the same was shifted further to 1070 / 1179 cm-1 due to nano copper coating over polyaniline.

To study the biofouling resistance of the treated net can be evaluated by different methods. The field evaluation of the cage net showed the excellent biofouling resistance after 90 days exposure in the estuarine environment. The experiment was repeated by constructing a cage

with treated and control panels and exposed in the Vizhinjam coast for 7 months (fig 1). The fishes grown in the cages and controlled environments were compared and exhibited significant difference in growth was shown.

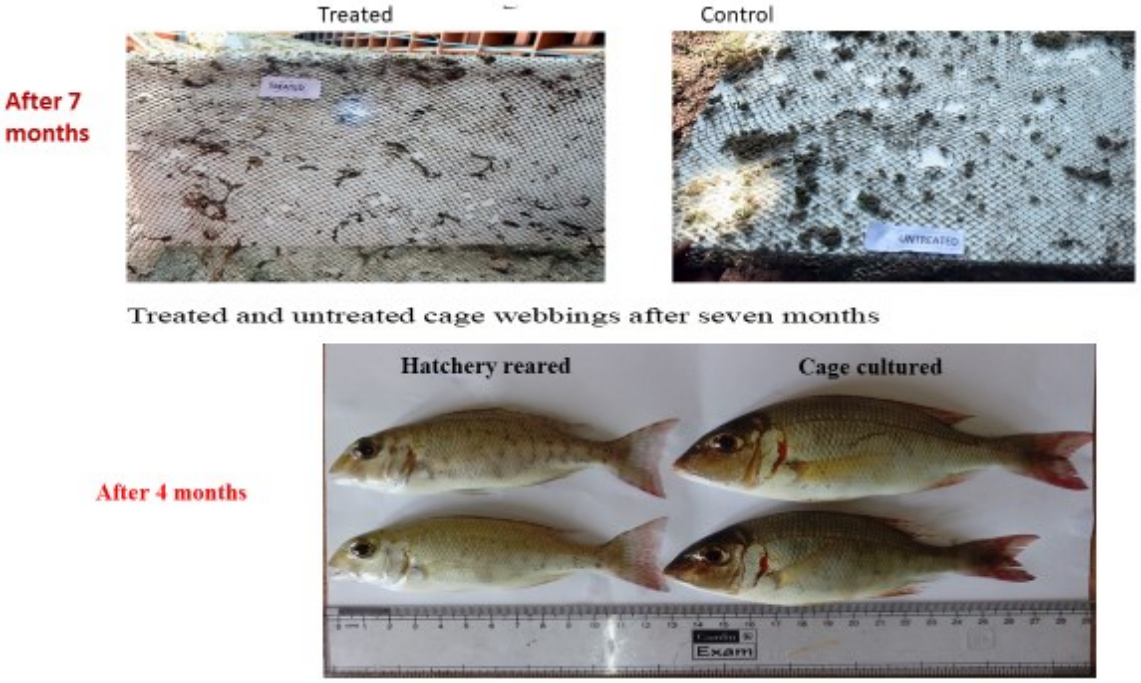

Fig 1. Control and treated net after 7 months exposure in the marine environments.

Deterrence of biofouling organisms to the treated surface was tested by cyprid assays. The treated surfaces were exposed to the testing organisms in natural or articifical seawater at controlled environments. Callow et al 1997 described assays using microorganisms like Ulva zoospore over the treated surface. The exposed surface in controlled environment were evaluated based on the attachement of spores. Callow et al and Schultz et al described about the determination of adhesive strength using a calibrated flow channel. Diatom assays were generally carried out using Navicula perminuta by suspending the treated surface in artificial seawater containing chlorophyll a 0.30 ug ml-1. After 2 h exposure the surface were evaluated for the adherence and deterrence of organisms. Antibacterial property of the biocide treated surfaces were evaluated using two marine bacteria viz Cobetia marina and Marinobacter hydrocarbonoclasticus. The former bacteria is considered first settled microbes over marine exposed surfaces. The measurement were carried as per the protocols described by Akesso et al.

Societal Issues

As with any emerging technology, the full consequences of pervasive incorporation into society are currently unknown. For example, what are the outcomes if the byproducts of 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, health environment and safety issued. The ethical and legal ramifications of nanotechnology are primed for public consideration. The greater the awareness and

understanding of nanotechnology 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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Inland Fisheries– CIFTs Interventions in Harvest sector

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Introduction

Inland fisheries are any activity conducted to extract fish and other aquatic organisms from "inland waters". Inland fisheries serve important economic, cultural, and recreational roles and play a major role in sustainable ecosystem function throughout the world. More than 60 million people in the developing world work with various aspects of inland fisheries. Individuals can relatively easily begin fishing in inland waters because basic equipment needs (e.g., nets, hooks, traps) are generally inexpensive and do not require substantial skill to operate or maintain. Inland fisheries are predominantly small-scale in nature, but large-scale and commercial inland fisheries do make a contribution to livelihoods and food security. Exploitation of fisheries in the inland areas of the country was insignificant in the earlier years where fishing was being conducted purely on a subsistence level. The last few decades have witnessed many technological advances in fishing systems in inland waters.

Technological developments in inland harvest sector

Fish capturing methods are varied in different inland water bodies depending on topography, ecology and habitat of the fishery resources. Unlike marine sector, the extent of suitable technology applications in inland fishery sector is very low and the fisherfolk engaged in small scale fishing in reservoirs, lakes and rivers are in a socio-economically underprivileged condition. ICAR-Central Institute of Fisheries Technology for the last six decades has been engaged in research and development of efficient harvesting systems for inland fishing sector of the India. Appropriate craft designs and improved gear designs been developed and introduced for the inland fisheries. Considering the declining fish production and various environmental impacts associated with fishing, the institute has shifted its focus from increasing catch to responsible and eco-friendly fishing and developing technologies for sustainable harvesting with reduced emissions. The institute is involved in the design and optimization of a range of crafts and gears which has contributed to the advancement in inland harvest sector in the country.

Low cost alternative materials for conventional crafts

Traditionally, wood is used for construction of fishing vessels in India which has become scarce and costlier. Focused attention has been given in identifying alternate materials for fishing vessel construction, in order to reduce the dependence on traditional scarce wood species. Cheaper and readily available cultivated wood species with short life cycle such as rubber wood, fortified with dual preservative treatment using 7.5% ASCU and creosote, has been identified for construction of canoes operated in backwater and coastal fisheries. A number of preservative treated rubber wood canoes have been distributed for field operations by fishermen groups and cooperatives. The cost of the canoe is 35 – 40% less than a canoe of same size built of ‘Anjili’, the usually used wood. This saves the depleting forest wealth, helpsthe rubber farmer to get a better price for his underutilized wood and gives a

durable, maintenance free boat at affordable cost to the poor fisherman especially of the South West and North East where rubber trees are grown. Designs of fiberglass crafts have been developed for operation in inland waters. Fibreglass sheathing as protection against borer attack and biodeterioration and as preventive against environmental pollution while using preservative treated wood in boat construction has been popularized, in traditional sector. Use of Aluminium alloy for construction of inland and coastal fishing craft has been demonstrated. Durability, light weight, corrosion resistance, toughness and resilience, low maintenance and high re-sale value make aluminum alloy a good material for construction of fishing craft.

Treated Rubber Wood Canoe

Rubberwood comes as a by-product from the rubber plantations which can be efficiently utilized for fishing boat construction after upgrading by chemical preservative treatment. The institute has successfully designed and constructed rubberwood canoes treated with dual preservatives and combination treatment technology for marine and brackish water fishing. The cost of the canoe is 35-40% less than a canoe of same size built from wood. It ensures a good market for less utilised rubber wood, fetching good income for the farmer.

Coconut wood canoe

Institute developed technology for effective utilization of coconut wood for canoe construction. The standardised parameters for preservation help to enhance the physical and mechanical properties of the coconut wood. Also helps in the effective utilisation of the old coconut trees which are often discarded. The reduction in cost, when compared to traditional wooden canoes is estimated to be around 30%.

FRP boats

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. Safe and durable fishing boats of Fibre Reinforced plastics (FRP) following scientific designs and making use of Nano-Resin technology were developed. FRP sheathed rubber wood canoes (both treated and untreated) were also constructed which were found to be in sound condition even after 26 and 16 months field operation respectively.

FRP coracle

ICAR-CIFT has been instrumental in developing and improving fishing techniques in reservoirs. Traditionally they are made of a split bamboo frame covered with either few animal hides or plastic sheets and is tarred to make it waterproof. Apart from being simple and inexpensive, coracle has very good manoeuvrability in waters. Traditional coracles are less durable and require frequent maintenance also. FRP coracles which are safe, cheaper and durable following scientific designs for reservoir fishing were developed by the institute. Improvements in FRP coracle such as Marine Grade FRPs for better longevity, design upgradations were made over the years.

Solar powered boat

The increasing fuel cost causes substantial financial burden to fishers. Taking this to account, ICAR-CIFT designed and introduced a multipurpose solar powered boat suitable for inland water bodies including aqua farms to promote the renewable energy utilization. Solar powered boat can be used for gillnetting, lining and recreational fishing. The boat is capable of running for 2.5-3hrs after complete charging and attains a speed of nearly 4 knots in calm waters. The twin hull construction gives high stability during the fishing activities and deck area is wider compared to a similar sized conventional boat. The navigational lights are also run by the solar power produced which is an additional feature compared to traditional boats which facilitates safe fishing during early morning and late night. Though this boat is two times costlier than the conventional boat, due to the cost of photovoltaic cells, battery bank and control system, it is compensated by minimum operational and maintenance cost.

Design modifications and optimization of fishing gears

Introduction of modern gear materials, have directly influenced and brought about important changes in the design, dimensions and method of handling fishing gears. Extensive use of synthetic materials like polyamide, polyethylene and polypropylene have perceived in 1960s which created a revolution in fabrication of fishing gears. Today, the entire fisheries sector uses only synthetic fibers for gears especially the polyamide monofilaments. The efficiency of fishing gears are influenced by factors such as mesh size, colour, fishing height, hanging ratio, yarn/twine diameter and gear material. Improvements /design modifications as well as optimum mesh parameters will help to reduce overexploitation and capture of juveniles and bycatch to a minimum. Technological interventions are made by the institute for optimization and improving the catch efficiency of the fishing gears.

Gillnets

Gill nets are the predominant fishing gear in inland fishing. The simplicity of its design, fabrication and low manpower and energy requirement for operation make gillnets very popular especially in the inland sector. By the 1950s, the material substitution by synthetic fibres revolutionized the gillnet sector. Over the years, many need based changes have taken place in gillnets with respect to the material used, dimensions, net design, mesh sizes, mode of operation. ICAR-CIFT has conducted extensive research to improve the design and operational parameters to make gillnet efficient for inland waters. Optimization in the mesh sizes, hanging ratio, introduction of suitable materials with specific characteristics like thickness, colour were developed. Optimum mesh size for the sustainable harvest of major fisheries resources in reservoirs were also estimated. Frame nets and trammel nets were also introduced in reservoirs which are observed to be efficient where the fish population is sparse and comprising of large size groups.

Pots and Traps

Various indigenous pots and traps are operational in the inland waters of the country. Traditional traps made of natural materials have intrinsic limitations such as a short life span, bulkiness, and inability to be stacked among others. Comparative studies demonstrate that indigenous traps are less effective than modern, species-specific traps. ICAR-CIFT has

contributed significantly to the documentation and development of different species-specific traps designs. Collapsible fish traps, ring traps, are some of the trap designs developed and popularized. ICAR-CIFT has designed and developed two different designs of innovative collapsible fish trap with dimensions of 1 m ×0.6 m ×0.6m &1.5 m x 0.8 m for fishing along the backwaters. HDPE webbing of 80mm mesh size rigged with iron bar as frame was used and two funnels measuring 35cm Ø were attached both the sides to allow fish to enter. These traps were supplied to the traditional fishermen and experimental trials were conducted along backwaters of Kerala. The design is simple and 40% lighter in weight when compared to the conventional traps. Durability of the trap is 3-4 times more than the conventional traps.

Stake nets/bagnets

The stake nets are widely operated in the estuaries and backwaters of Kerala. ICAR-CIFT has documented the design of stake nets along Cochin coast and catch composition in relationship with lunar cycle and tidal variations. The findings from the research recommended the minimum mesh sizes to protect juveniles of shrimps. To tackle bycatch issues in Hooghly riverine systems, square mesh windows were introduced in the bagnets. The invention has facilitated the escape of juvenile hilsa, *Tenualosa ilisha* and many fast swimming fishes to achieve sustainability.

Biofouling resistant polyethylene cage aquaculture nettings

Fish cage culture is currently regarded as an important method for increasing the productivity of inland waters. In cage culture, however, fouling and the associated reduction in water exchange is a common issue. Biofouling in aquaculture cage nets causes occlusion of mesh openings, thereby increasing weight and drag, deformation of cages due to the ensuing stress, reduction of volume, thereby decreased stocking density per area, anoxic condition due to disruption of dissolved oxygen flow, blocking of food waste diffusion, restriction of water exchange, increased hydrodynamic force, all of which adversely impacted fish health. It has been reported that removal of fouling from a cage net costs 25% of the total project budget. Cages are fabricated mainly with high density netting whose nonpolar nature makes incorporation of antifouling biocides difficult. The surface of polyethylene needs to be modified to develop strategies against fouling. The novel approach employed by ICAR-CIFT was to synthesise a coating of polar or conducting molecule over non-polar polyethylene to incorporate antifouling biocides thereby rendering protection to protect the polyethylene aquaculture cage nets from biofouling. In addition to fouling control, proper netting materials for cage construction, optimal mesh size, etc. were also recommended.

Environmental impacts of fishing

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General ecological impacts due to fishing

Fisheries have great significance in terms of food security and the economy of a country at the same time they have a significant impact on ecological processes on a large scale, and badly managed fisheries develop excessive fishing capacity, leading to overfishing with social and economic consequences. An ecosystem that was originally stable, mature, and efficient becomes stressed and immature as a result of overfishing. By targeting and reducing the abundance of high-value predators, fisheries deeply modify the trophic chain and the flows of energy across the ecosystem. Fishing also alters habitats by destroying and disturbing bottom topography and the associated habitats including seagrass, seaweed, mangrove, algal beds, coral reefs, and benthic communities. The alteration of the habitat by various fishing activities may be physical like the introduction of artificial structures or mechanical such as the use of bottom trawls, or chemical such as the leaching of pesticides, heavy metals, drugs, hormones, etc to the marine environment result in changes in productivity. Some aspects of fishing can have significant and long-lasting effects, e.g. destructive fishing techniques or inadequate fishing practices; pollution, use of ozone-depleting refrigerants, dumping at sea of plastic debris that can entangle marine animals or be swallowed by turtles; loss of fishing gear, possibly leading to ghost fishing; lack of selectivity, affecting associated and dependent species, resulting in wasteful discarding practices, juvenile mortality, added threat to endangered species, etc. Poorly-managed fishing practices can damage coastal ecosystems and contribute to ecosystem contamination with food residues, waste, antibiotics, hormones, diseases, and alien species.

Fishing involves the construction of the fishing vessel, gear & other accessories which channeled the harvest process. Both of these processes cause many environmental impacts. During the last 50 years, the introduction of synthetics in construction/fabrication gradually replaced natural materials such as wood for fishing boat construction and natural fibres such as cotton, manila, sisal, jute, coir, etc in the fabrication of fishing gears due to their high breaking strength, high resistance to weathering, low maintenance cost, long service life and better uniformity in characteristics also affect the marine ecosystems.

Environmental impacts of major boat building materials in aquatic system

Several technologies evolved over the years in the fishing industry which have improved the fish catch as well as the effort and the related inadequate practices leading to damage to the ecosystem and these ecological impacts were well explained in much of the literature. Hence, this chapter mainly dealt with the environmental impacts of boatbuilding materials and emissions from fishing.

In fishing boat construction, the common materials used in India include wood, glass/fiber reinforced plastic (FRP/GRP), aluminium, steel, plywood, ferrocement, etc. While selecting a material for boat construction some basic factors to be considered are type, size, speed, the shape of the vessel, availability and suitability of the material, and economic and environmental viability. The performance and efficiency of a boat are directly dependent on the choice of the boat-building material which also has a direct impact on the environment. By taking these facts into account, a boat designer can select the best possible alternative for building a boat of high efficiency and durability. A fishing boat is made up of different components and their construction is a complex process. Certain quantities of greenhouse gases (GHGs) are produced in the process of manufacture, transportation, and utilization of these components, which can be converted in terms of equivalent CO_2. Every ocean has marine debris, and more than 60% of it is plastic that comes from the fishing industry, offshore platforms, recreational shipping, etc (Cheshire et al., 2009; Eriksen et al., 2014; Pham et al., 2014., Richardson et al., 2019).

At present, the larger class of fishing vessels are made of steel while vessels belonging to the medium and lower categories mostly use wood for construction. Fiberglass, ferrocement, and aluminium are the new substitutes for conventional boat building materials as these can improve the lifespan of the boats. However, traditional fishing boats still play a vital role in this era. Despite its obvious advantages, all boat-building materials are susceptible to the effects of the marine environment, for example, glass fibres are the most selected material for boat construction, which are vulnerable to the effects of sunlight in marine conditions. Fiberglass-reinforced plastic (FRP) is a polyester resin-based composite, reinforced with fine strands of glass filaments. Glass fiber is prone to osmosis, and gelcoat gets faded in sunlight resulting in the attack of UV radiation. FRP fragments have a higher density than seawater and will tend to concentrate nearshore. The polyester resins or epoxy resins in the FRP undergoing physical & chemical degradation lead to the release of microplastics which affects the environment. Marine organisms consume these plastic particles and end up in the human food chain causing severe health issues. Additionally, the deteriorating and peeling paint with high concentrations of tributyltin and lead from the abandoned boats may provide a long-term environmental issue

Aluminium alloys are prone to corrosion if untreated or damaged. When new alloys are exposed, an oxide layer is formed on their surface but this oxide layer does not protect the alloy in the long term when exposed to marine environments. Periodically the paint system will need to be removed in areas of stress and the corrosion treated. Careful inspection on an annual basis of all weld seams helps in early identification of the occurrence of this problem. Aluminium reacts with some copper-based antifouling paints causing serious corrosion in environmental conditions. Therefore, antifouling containing metallic copper or cuprous oxide should never be used on aluminium, whilst copper thiocyanate-based antifouling can be used if the aluminium is primed properly.

The most common form of corrosion in steel is rust. Such a reaction will take place only in the presence of water. A marine environment is therefore an ideal place for rust to occur. Due to the high flexibility and strength of steel, it is hard to break, but impact damage may well result in a dent owing to the metal stretching and deforming locally. This can present problems for a protective coating, which may not be so flexible.

The fibrous nature of timber means that it has a tendency to absorb moisture from the atmosphere, and swell and contract to varying degrees depending on the type of construction. For a varnish or paint coating to stay intact it has to be quite flexible in nature. Moisture content in wood allows the growth of fungal spores, which leads to rotting and decay. Wood can also be subjected to the attack of marine borers, which eat the wood fibers. Therefore, it needs to be protected by good-quality preservatives and coatings. Many different kinds of wood can be used, which can differ immensely.

A comparative table giving the carbon consumption in the production of these materials

Material	Net carbon emissions (kg C/metric) [1]	Net Carbon emissions including Carbon storage within material (kg C metric ton)[2]
Framing Lumber	33	-457
Medium density fibre board	60	-382
Steel	694	694
Aluminium	4532	4532
Plastics	2502	2502

Net carbon emissions in producing 01 ton of material (OECD, 2010)

While considering the environmental and economic sustainability of different boat building material, wood is an ideal material still preferred for marine boat construction. Wood is a functionally efficient material which reduce carbon footprint thereby reducing the environmental impact and simultaneously balance the cost objective. Environmental impact of any material can be evaluated through Life cycle assessment procedure or LCA. The environmental impact of wood from the very first state of harvesting to the end of the product was studied and compared with other materials and found that wood as a material for boat construction contributes less pollution to the environment compared to concrete, steel, aluminium etc.

Studies have found that wood products have less embodied energy and are more environmentally friendly as they are involved in less carbon footprint as well as air and water pollution. Furthermore, residues of wood industries are utilized in either by-product manufacturing or fuel and clean bio-energy. As forests act as a carbon sink and prevent

climate change and greenhouse gas, increasing wood use ensures sustainable development by reducing emissions, increasing renewable wood use, and thus helping the national economy.

Fishing Vs Energy use

Commercial fishing operation mainly utilizes fossil fuels which result in the emission of greenhouse gases. The active cost of fishing is less understood and consequently receives less attention to GHG emissions than the direct impact on fishery stock and marine ecosystem. Similarly, in the harvest process, several reoccurring inputs are required for every fishing operation, viz. fuel, lubricant, ice, freshwater, etc. These inputs have their own carbon footprint value for construction/extraction/process, especially fuel contributes more than 95% out of all the components. Despite the fact that the prevailing pre-harvest phase of marine capture fisheries lacks general detail and standardization about LCA/carbon footprint studies; such studies and their findings can be useful in formulating constructional/operational recommendations to improve the environmental performance of fisheries, under the context of an ecosystem approach to fisheries along with future certification and different eco-labelling of fisheries. Studies related to pre-harvest, harvest, and post-harvest fisheries LCA/carbon footprint analysis would be more appreciated by policymakers for the regulation of fishing boat yards and other related fishing ventures.

Based on behaviour and habitat, there are different methods of fish harvest and on the basis of their operation, the quantum of fuel and energy requirement also varies. As per the study by Parker et al., 2018, the world fishing fleet burned about 40 billion liters of fuel and emitted 179 million tonnes of CO_2 equivalent and other GHGs to the atmosphere. Overcapacity and irresponsible use of fossil fuels leads to increased levels of fuel consumption in fishing contributing to climate change in the long run. India contributes 134 million metric tonnes (2.7%) of CO_2 emission due to total marine capture fisheries, against 90 million metric tonnes (3.9% of global production) of fish production. The emissions due to fishing were not given importance as compared to other sectors for emission in India, however, the contribution of the fisheries sector is negligible which roughly may be <1% of global GHG emission. The other associated important environmental parameters by which the health of the environment, humans, and resources can be evaluated due to the fishing process are; terrestrial acidification, formation of fine particulate matter, Water consumption, Ionizing radiation, ozone formation, human carcinogenic toxicity, fossil resource scarcity, mineral resource scarcity environment deterioration, human health, resource depletion, and stratospheric ozone depletion, etc.

Different types of vessel and gear combinations are used for fishing to exploit various fish stocks. The important fishing practices are trawling, gillnetting, longlining, dol netting, purse seining, etc. One major reason for the substantial increase in eq. CO_2 emission by the construction process is the increase in the number and efficiency of fishing boats otherwise called overcapacity, which need more inputs and equipment, resulting in more eq. CO_2 emission.

In modern fisheries, the major direct and indirect energy inputs can be systematically analysed using process analysis and input-output techniques. Mostly direct fuel inputs are used primarily for vessel propulsion. On average direct fuel energy inputs account for between 75 and 90% of the total energy inputs, irrespective of the fishing gear used or the species targeted. The remaining 10 to 25% generally depends on vessel construction and maintenance, and the provision of labour, fishing gear, bait, and ice if used which depends on the character of the fishery and the scope of the analysis conducted. The secondary energy-consuming activities, which include onboard processing and storage are negligible compared to primary energy consumption in terms of fuel burned. The study of environmental burden is important in relative resource-use analysis and greenhouse gas (GHG) impacts in climate change mitigation. It has got emphasis due to the high instability in fossil fuel costs which has potentially lasting impacts on the economic performance of various fishing systems.

The effects of fishing and its implications on ecosystems, especially from the boat-building sector or the usage of energy, fuel, and emissions, were not particularly addressed and are anticipated to have significant effects on ecological sustainability and food security globally.

Testing of fishing gear and craft materials

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Introduction

Traditional fishing gears used earlier, till 1950s were mostly made of natural fibres such as cotton, manila, sisal, jute and coir. In the late 1950s, with the introduction of man-made synthetic fibres, natural fibres used for the fishing gears have been substituted by these synthetic materials. This transition was mainly due to the highly positive properties of these fibres such as highly non-biodegradable nature, high breaking strength, better uniformity in characteristics, high abrasion resistance, low maintenance cost and long service life. Most important polymer/synthetic fibres used in fishing gears 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). Aramid fibres, Ultra high molecular weight polyethylene (UHMWPE) and liquid crystal polymer are later additions to this group.

Tests for identification of synthetic fibres

Different groups of synthetic fibres can be identified by various methods.

Water test: Identification of synthetic fibres can be started with this test. In a short piece of netting yarn, tie a simple overhand knot and put the piece into a vessel filled with water. Air bubbles in the material must be squeezed out by hand underwater. Based on water test, netting materials can be classified into two groups; (1) synthetic fibres which float in water (PE & PP) (2) fibres which sink (all other synthetic fibres).

Burning test: In the burning test, the nature of burning and smoke in the flame as well as after leaving the flame are observed. The netting material can be brought near to the flame and after removal from the flame, observe the smell of smoke and the residue. Synthetic fibres shrink and melt in the flame, the melting substance drips from the flame mostly forming a bead or a hard irregular residue. The changes in different synthetic fibres during burning test is given in table 1

Solubility test: Solubility test is a relatively simple chemical test. Fibres of the sample to be tested should be in a loose form. The netting yarn must be untwisted and the fibres can be cut into small pieces of 1cm length. Coarse material like split fibres and especially monofilaments should be cut to very small pieces. Take 10-15ml of the solvent into the test tube and put the sample pieces into it. The results of the reactions are shown in table 2.

Table 1. Burning characteristics of synthetic fibres

Material	PA	PES	PE	PP
In flame	Melts, burns wi light flame, whi smoke, meltir drops fall down.	Melts, burns wi light flame, soo black smok melting drops fall down.	Shrinks, curls, mel and burns with lig flame, drops melting fall down.	Shrinks, melts ar burns with lig flame melting dro fall down.
After leaving th flame	Stops burnin melting drops ca be stretched into fine thread.	Stops burnin melting bead ma be stretch into fine thread.	Continues to bu rapidly, hot meltir substance cannot be stretched.	Continues to bu slowly, hot melting substance can be stretched.

(Source: Klust, 1982)

Table 2. Identification of synthetic fibres by solubility test

Reagent	Type of fibre			
	PA 6	PES	PE	PP
Hydrochloric acid/HCL (37%) 30 minutes at room temperature	+	o	o	o
Sulphuric acid/H_2SO_4 (97-98%) 30 minutes at room temperature	+	+	o	o
(1) Dimethylformamide/HCON $(CH_3)_2$ 5 minutes boiling	+	+	o (2)	o (2)
Formic acid/HCOOH (96-100%) 30 minutes at room temperature	+	o	o	o
Glacial acetic acid/CH_3-COOH 5 minut boiling	+	o	o	o
Xylene/C_6H_4 $(CH_3)_2$ 5 minutes boiling (inflammable)	o	o	+	+
Pyridine 30 minutes at room temperature	o	o	o	o

(Source: Klust, 1982)

+ = soluble, o = not soluble, (1) = Dimethylformamide is decomposed by exposure to light even when stored in a brown bottle, needs to be stored
away from light preferably in a cool place, (2) Destroyed but not soluble

Properties

Synthetic netting materials are generally resistant to biodeterioration. 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. For quality evaluation and selection of appropriate material for different gears, knowledge on

various properties of netting yarn are required. The numerical values of these properties are determined through standard test procedures. As far as the fishing gear purpose is concerned, properties which are of importance are as follows and their standard method references are also provided.

Diameter: The diameter of netting material is an important factor influencing the fishing gear performance. 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. Diameter of a material is dependent on the type of polymer, type of yarn, size of yarn, specification and construction. Diameter is usually determined as the distance between the two edges of the yarn/twine measured on a travelling microscope and expressed in mm. Testing is done in accordance to IS 5815 (Part1): 1971. The test specimen shall be conditioned to a state of moisture equilibrium in standard atmosphere at 65$\pm$2 percent relative humidity and $27^0\pm 2\ ^0$C temperature (IS 6359: 1971). Mount the specimen horizontally under standard tension between two grips. The image is focused and reading of the two edges of the images is noted, one by one. The difference between the readings when the cross-wire coincide with the upper edge of the sample and with the lower edge of the sample gives the diameter. The tests shall be conducted on ten samples selected at random and the mean value is calculated with an accuracy of 0.01mm.

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. For the same kind of material, lower Rtex means thinner material and generally costs less while buying on a mass basis. For testing, the sample to be conditioned to a state of moisture equilibrium in standard atmosphere first (IS 6359: 1971). Testing is done in accordance to IS 5815 (Part2): 1970 (Reaffirmed 2014). From the conditioned sample, suitable lengths shall be reeled off keeping the standard pre-tension. In the case of twine, care should be taken to see that twists are not altered. For testing in wetstate, the test specimens after cutting to standard length under standard pretension shall be immersed in tapwater at room temperature for a period of not less than 12hrs. Apply the standard pre tension to the sample and measure a length of 10 meter or its multiples and cut. Similarly prepare10 samples of the required length. Weigh the prepared samples using the balance to an accuracy of 0.01 g and calculate the mean weight. Report the linear density as Resultant tex or Resultant denier.

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. 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.

The sample to be tested to be conditioned to a state of moisture equilibrium in standard atmosphere (IS 6359: 1971). For measuring twist (IS 5815 (Part 3): 1970 (Reaffirmed 2014)), mount the test specimen between the clamps (set at 25 cm apart) of twist counter by applying standard tension (tex/2) for straightening it out. Set the revolution counter to zero. The twist is removed by revolving the rotating clamp to untwist the specimen until the strands are parallel. Note the reading on the revolution counter to two places of decimal and designate it as outer twist after making the readings for one meter. Cut off all the strands except one and again set the counter to zero. Revolve the rotating clamp in the opposite direction until the yarns are parallel. Note the reading on the revolution counter and treat it as the inner twist. Convert the value for one meter. Repeat the tests with 10 samples selected at random. The mean value shall be reported as the turns per meter.

Breaking load: The breaking 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. Knotting 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. A length of yarn is extended until it reaches the load at rupture by a suitable apparatus, The Universal Testing Machine, that records the applied force (IS 5815 (Part4): 2018 (Reaffirmed 2016). The test specimen shall be conditioned by exposing to the standard atmosphere (IS 6359: 1971). A period of 24h exposure is generally sufficient. Samples to be tested in the wetstate shall be immersed in tap water, without wetting agents at a temperature of ($20 \pm 2\ ^0C$) for a period of not less than 12h. Mount the conditioned test sample between the grips of the UTM so that the axis of the specimen is parallel to and coincidental with the direction of the applied force. Wet samples shall be tested immediately after removal from the water. Apply the force on the test specimen until it breaks. Adjust the speed so that the mean duration of test shall be $20 \pm$ seconds. Repeat the test with 10 samples and the mean is taken for the evaluation of results. Breaking load is expressed in Newton (N).

Elongation : 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. 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. Elongation is also tested in UTM and sample preparation procedure is similar as above described in breaking load. Mount the conditioned test sample (IS 6359: 1971) between the grips of the UTM so that the axis of the specimen is parallel to and coincidental with the direction of the applied force. Set the load and the stroke sensors to zero and start the test. Adjust the speed so that the mean duration of test shall be 30 ± 3 seconds. Apply the force on the test specimen until it breaks. Ten tests

are usually conducted for a batch and the mean is taken for the evaluation of results (IS 5815 (Part4): 2018 (Reaffirmed 2016).

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. For testing the abrasion resistance, the principle is to apply a certain number of frictions or abrasion cycles and measuring the remaining breaking load of abraded material expressed as the percentage of initial breaking load. For measuring the abrasion resistance, connect the Yarn abrasion testing machine with power supply. Fix the samples on hooks provided on the machine and load the other end of each sample with weight equal to standard pretension (tex/2). Set the speed of abrasion roller and start the abrasion roller Machine will stop after counter reach the preset value. Measure breakload of the samples at specified rotation cycles. Continue with the test till the yarn breaks. Determine the breaking load (IS 5815 (Part4): 2018 (Reaffirmed 2016) of the samples initially and at regular intervals on exposure and correlate with the exposure period.

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 depending on the type of polymer and fibre. The rate of deterioration is generally assessed by the loss in breaking strength (IS 5815 (Part9):1994 (Reaffirmed 2015). Weathering resistance is measured by exposing the material to natural sunlight. Test samples are suspended without tension on nails set at 1cm apart in rectangular wooden frame with sufficient ventilation and to prevent temperature from building up excessively. Mounted samples are to be held in a north-south direction at an angle of 450 and to be kept in a place where sunlight will fall directly on the sample during the wholeday. Determine the breaking load (IS 5815 (Part4): 2018 (Reaffirmed 2016) of the samples initially and at regular intervals on exposure and correlate with the exposure period. Weathering resistance can also be studied in controlled conditions in the laboratory by using Weather O meters with artificial light sources such as fluorescent arc, UV arc, Carbon arc, Mercury arc and Xenon arc. Xenon arc is a good substitute as it approximates solar radiation and gives very steady illumination. Weathering studies in Xenotest take only one-seventh to one tenth of the time than the samples exposed to natural conditions.

Testing of Boatbuilding Timbers

Physical properties

The common physical properties tested for wood are Odour, lusture, texture, fluorescence, density, specific gravity (Method I (IS 1708:1986 (Part 2) reaffirmed 2015), grain, moisture content, etc. Testing of wood shall conform to IS: 1708 (Part 1 to 18) – 1986. The weight of

water in wood given as a percentage of oven-dry weight is the moisture content. Determination of moisture content by (IS 1708:1986 (Part 1) was reaffirmed in 2015.

***Thermal conductivity*:** The rate of flow of heat through wood at unit temperature difference across unit thickness is the thermal conductivity. Density, moisture content, extractive content, grain direction, structural irregularities, fibril angle, and temperature are the factors that affect the thermal conductivity of wood.

***Durability*:** Heartwood contains dead cells and in some species presence of highly toxic extractives resists decay. Hence, durability classes are appropriate for heartwood only. All untreated sapwoods are non-durable. On the basis of natural durability, timbers are classified into five classes.

- Very durable: These types of timber structures are used for making permanent structures in contact with ground or water. Used to manufacture railway sleepers, bridging timbers, marine piling, fencing, transmission poles, etc. Service life >10 years
- Durable: Wood having high durability are good candidates for the exposed parts of permanent structures which are not in direct contact with the ground. They are used to make frames, keels, and decking of boats. Service life 5 – 10 years
- Moderately durable: Moderately durable woods should never be used in direct contact with the soil. Preservative-treated wood can withstand exposure to damp conditions. They can be used for parts of some vehicles and boats. Service life 2 – 5 years
- Non-durable: These types of woods can safely be used for internal joinery and furniture after preservative treatments. Service life <2 years

Mechanical properties

Mechanical property divides into two, Elastic property and Strength property. The elastic property indicates the stiffness or deformation of a material eg. Modulus of elasticity; modulus of rigidity, etc. The deformation takes place instantaneously as a load is applied and the load is recoverable when it is removed. Mechanical properties value is given in terms of stress and strain. Strength is the ability of the material to carry applied load or forces and resists deformation (compression, tension, bending, shear, hardiness, wear resistance, etc. The standards followed for the tests are follows;

- Determination of Volumetric Shrinkage (IS 1708:1986 (Part 3) reaffirmed 2015)
- Static bending strength (IS 1708:1986 (Part 5) reaffirmed 2015)
- Compressive strength parallel to grain (IS 1708:1986 (Part 8) reaffirmed 2015)
- Compressive strength perpendicular to grain (IS 1708:1986 (Part 9) reaffirmed 2015)
- Shear strength parallel to grain (IS 1708:1986 (Part 11) reaffirmed 2015)
- Tensile strength parallel to grain (IS 1708:1986 (Part 12) reaffirmed 2015)
- Tensile strength perpendicular to grain (IS 1708:1986 (Part 13) reaffirmed 2015)
- Nail and screw holding power (IS 1708:1986 (Part 15) reaffirmed 2015)

Chemical properties

The chemical composition of wood cannot be defined precisely for a given tree species or even for a given tree. Cellulose, hemicellulose, and lignin are the principal components of the cell walls which constitute wood. The other properties under consideration include pectic substances, waxes & related substances, proteins, and ash.

Anatomical studies: FAA (Formalin-Acetic acid & Alcohol mixture) is used for sudden stoppage of living processes that occur in green samples for future observations. This is the most important step in the process of making microscopic preparations. Fixation in wood samples is the preservation of all structural and cellular elements in their original state as much as possible. For future analysis, wash samples in distilled water twice or thrice. Then it is mounted on a microtome and sections are taken. Through this method, the green timber samples can be stored indefinitely in FAA without decay.

FAA Preparation: To prepare 100ml Formalin-Acetic acid & Alcohol mixture following chemicals are required.
Ethyl alcohol (95%) -50ml
Glacial acetic acid - 5ml
Formaldehyde (37-40%) -10ml
Distilled water -35ml
Caution: Mix well and keep in an air-tight bottle. Followed by sectioning, staining, and mounting for anatomical examinations under microscope.

Further reading

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Advances in Fish Processing Technologies

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Introduction

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

Conventional Processing Technologies

Live Fishery Products

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

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

Chilling

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

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

Advanced Packaging Methods for Chilled Fishes

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

Frozen Fishery Products

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

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

Dried and Salted Fishery Products

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

Smoked Fishery Products

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

Sous-vide products

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

Thermal Processed Fishery Products

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

Specialty Fishery Products

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

Surimi

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

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

Fish sausage

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

Dry Ice for transporting High Value Products

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

Advanced Processing Technologies

High Pressure Processing

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

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

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

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

Conclusion

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

Low temperature preservation of fish products

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Introduction

Fish, being a rich source of all the nutrients viz., omega-3 fatty acids, quality and easily digestible proteins, essential minerals, and vitamins, has gained importance as a health food in human diet. These advantages offer considerable benefits to fish as a means to achieve nutritional as well as social security. Better awareness regarding this biomass as a potential source of nutrients has created increased interest in effective exploitation of these resources. However, their richness in nutrients as well as high moisture content increases its perishability, necessitating the processing and preservation of fish mandatory soon after harvesting. Among the various preservation methods available, low temperature preservation viz., chilling as well as freezing has attracted interest of many researchers on account of its minimal changes in the texture and other characteristics of fish upon proper processing and storage.

Chilling

Shelf stability of fish is very important for ascertaining its availability to a wide range of customers across the globe. This can be assured only by proper handling and preservation techniques. Among the various preservation techniques, chilling assures effectiveness in delaying bacterial growth and prolongs the shelf life of fish. Although chilling is effective in delaying the spoilage, it will not inhibit the spoilage completely as the enzymes and bacteria will be active at the chilled temperature. The objective of chilling is to cool the fish as quickly as possible to as low a temperature as possible without freezing. The storage life of chilled fish in different forms of ice like flake ice, slurry ice, ozone-slurry ice ranges from almost 4 to 20 days depending on the species. Studies have indicated that for every 10^0C reduction in temperature, the rate of deterioration decreases by a factor of 2-3. Hence higher and faster rate of temperature reduction upon capture assures better and prolonged stability of the seafoods.

The most common and cheapest means of chilling seafood is icing. Other means of chilling include: Air chilling; Use of alternative methods like chilled water viz., Refrigerated sea water (RSW), Chilled sea water (CSW), Chilled fresh water (CFW); Chilling of fish by dry ice (solid carbon dioxide), liquid nitrogen, cold ammonia or other refrigerants, etc. Chilling is a relatively short-term means of preservation when compared to other techniques like freezing, canning, salting or drying etc.

Icing is widely employed for chilled storage of marine as well as fresh water fishes as well as shell fishes. Fishes are kept in a chill store in insulated boxes with proper icing prior to pre-processing. The major advantage of using ice for chilling the fish is its high latent heat of fusion which facilitates the removal of large amount of heat from the object to be cooled. 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 ambient temperature of 30^{O}C to 0^{O}C. Hence theoretically about 30% of ice is needed to bring down the temperature from ambient conditions to 0^{o}C. However, ice is needed to maintain the temperature as well as to accommodate the heat from the environment and hence in tropical conditions, a 1: 1 fish to ice ratio is ideal for ice storage. Icing of fish is very easy as it does not involve sophistication or high level of skill. Further it's easy availability is an added advantage. However, due to lack of knowledge icing is not properly practiced during fish handling and preservation. The proper use of ice can substantially reduce post-harvest losses and improve the quality of fish. In general, icing of fish is done in three stages during the post-harvest supply chain: on board fishing vessel immediately after harvest; after landing in the landing centre or before transportation; during retail sale. For icing to be effective, standard protocols like use of good quality ice, cleaning, dressing and sorting of fish for icing, proper layering of ice and fish etc. should be ensured.

Ice is available in several forms such as blocks, plates, tubes, shells, soft, chip and flakes. To ensure maximum contact of ice with the fish, proper selection of the size of ice particles and good stowage practices are needed. Flake ice is the most popular form of ice 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. On being smaller in size and less thickness with smooth edges, it also causes minimum damage to the flesh.

Shelf life of iced fish

Shelf life of food is the time period during which the food can be stored and displayed whilst still maintaining an acceptable quality or specific functionality. For fish, shelf life is the time from when it is taken from the water until it is no longer fit for consumption. Shelf life of chill stored fish is limited and in general, range for few days between 4 to 20. The stability of fish is dependent on various intrinsic as well as extrinsic factors. Various research carried out in this aspect has derived at a few general observations which reports that under ice storage:
Non-fatty fishes, white fleshed fishes, freshwater fishes, tropical fishes, flat fishes, thick skinned fishes have better storage stability than their counterparts viz., fatty, dark fleshed, marine, temperate, round, thin skinned ones, respectively.

Quality Changes in chilled fish

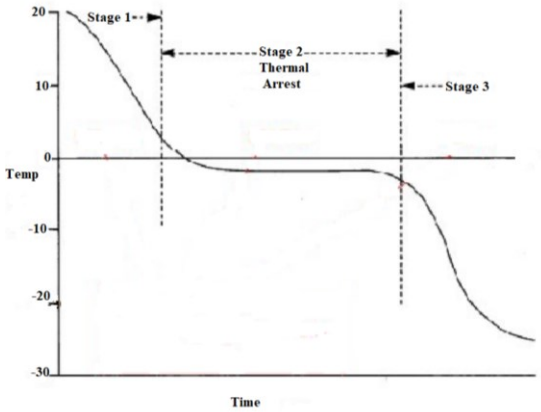
- *Weight loss:* The fish chilled with ice shows gradual weight loss upon storage. Losses which occur in iced fish are largely or entirely due to formation of free liquid drip. This is on account of quality changes viz., protein denaturation associated with the chilling and associated storage. Drip water carries with it a considerable percentage of soluble proteins, salts, other flavouring and nutritive components of the fish.
- *Discolouration:* Improper icing/chilling results in bruising, damage and consequent discolouration of flesh. Improper and delayed gutting of fish facilitate the powerful digestive enzymes to attack the viscera and belly walls resulting in belly burn or disruption at iced

temperature which also cause discolouration. It is well known that pelagic fishes with filled digestive tract may develop torn or burst bellies well before the signs of spoilage sets in.

- *Rancidity:* In case of fatty fishes, even at low temperature of 0 to 2ºC, rancidity may develop on account of fat oxidation and the rancid flavour becomes a limiting factor affecting its keeping quality during storage.
- *Shrinkage:* Shrinkage is a common phenomenon in fish packed with ice, particularly in the upper layers. The shrinkage in lean fishes are higher than that of fatty fishes as the subcutaneous layer of fat serves to reduce the evaporation of tissue moisture.
- *Weight gain:* Fish stored in refrigerated and chilled seawater exhibits the tendency to gain weight and uptake salt thereby limiting the application of this chilling system in seafoods.

Freezing

Low temperature preservation like freezing is the best method to retain the quality and freshness of fish and fish products for a long time. Freezing reduces the spoilage activity and extends the shelf life of the product. It 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. Freezing involves the cooling down of food materials from ambient temperature conditions to a temperature below the freezing point. Generally the freezing process has three stages; first stage (pre-freezing stage) corresponds to removal of heat from the food, when the temperature is reduced from ambient to freezing point. The second stage which is the freezing stage, is the period of transformation of water to ice through the whole mass of food. The second stage is also referred to as the zone of maximum crystallization. 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 all 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.



Freezing Curve of fish

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 0^0C but proceeds over a range of temperature. Thus, even at -30^0C, 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 or quick freezing produce large number of small and uniform crystals, thus reducing the possibility of shrinkage or rupture.

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 -1^0C to -2^0C; thus in order to reduce the thaw drip to minimum, the time spent in this temperature zone should be minimum. If the temperature of fish/fishery product is reduced from 0^0C to -5^0C 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 -30^0C such that the thermal centre of the fish attains -20^0C prior to its removal from the freezer. The time taken to lower the temperature of the thermal centre to -20^0C is termed as the freezing time. Based on this, most of the commercial freezers operate at temperatures of -35^0C to -40^0C. The major factors which affect freezing time include: Freezer type, Freezer operating temperature, Refrigeration system and operating condition, Air velocity in an air blast freezer, Product temperature, Product thickness, Product shape, Product contact area and density, Product packing, Species of fish

Freezing Systems

Freezing techniques have evolved with different modes of operation and the first man made freezing system was reported to be freezing using ice-salt mixture; followed by the developments in mechanical refrigeration. Mechanical refrigeration can broadly be classified into two: direct and indirect system wherein the direct system, the refrigerant absorbs heat directly from the material to be cooled while in indirect/ brine system, the refrigerant absorbs the heat that brine absorbs from the material to be cooled.

Based on this mode of operation, they are further classified as:

- *Freezing in Air*
- *Indirect contact freezing*
- *Spray or Immersion freezing*
- *Cryogenic freezing*

Air freezing

Seafoods can be frozen in air at temperatures ranging from –18° to – 40°C.

Sharp Freezing

Sharp freezers are cold storage rooms especially constructed to operate at and maintain low temperatures. Freezing time generally ranges from 3-72 hours or more depending on the conditions and the size of product. In this method, the product to be frozen is placed in a very cold room, maintained at temperatures in the range of –15°C to –30°C. In this system, the air within the room will circulate by convection, with little or no provision for forced convection.

Hence foods placed at these low temperatures are frozen comparatively slow, taking several hours or even days for complete freezing.

Air blast freezing

In an air blast freezer, fish is frozen by circulation of a stream of high velocity cold air either in a batch or continuously, typically in a duct or tunnel at -18 to -34°C or lower, moving counter current to the product at a speed of 1-20 meter/sec.

Continuous air blast freezers/tunnel freezers: In this type of air blast freezer, the fish are conveyed through the freezer (trolleys or they may be loaded on a continuously moving belt or conveyor) usually entering at one and leaving at the other.

Batch air blast freezers: Batch air blast freezers use pallets, trolleys or shelf arrangements for loading the product. The freezer is fully loaded, and when freezing is complete, the freezer is emptied and reloaded for a further batch freeze.

Air blast freezing is economical and is capable of accommodating products of different sizes and shapes. However it can result in excessive dehydration of unpackaged products if conditions are not carefully controlled, as well as undesirable bulging of packaged products which are not confined between flat rigid plates during freezing.

Modern designs of belt freezers are mostly based on the spiral belt freezer concept. In these freezers, a conveyor belt that can be bent laterally is used. The design consists of a self-staking and self-enclosing continuous 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 products are placed on the belt outside the freezer where it can be supervised. Both packed as well as unpacked 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 applied and the latter is observed to be more efficient.

Fluidized bed freezing is a version of air blast freezing wherein marine products like small sized prawns, uniform sized fillets etc. can be frozen by passing through meshed belts where they are fluidized by a stream of forced cold air moving upward through the bed at a rate sufficient to partially lift or suspend the particles. Freezing by this method is rapid and a minimum air velocity of 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 food 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 include more efficient heat transfer and more rapid rates of freezing and 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

Plate freezers consist of a vertical or horizontal stack of hollow plates, through which refrigerant is pumped at –40ºC. Fish products can be frozen by placing them in contact with these metal plate surface cooled by expanding refrigerants. This equipment consists of a stack of horizontal or vertical 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. In this method the packages must be of uniform thickness. A packaged product of 3 to 4 cm thickness can be frozen in one to two hours when cooled by plates at -35°C. Freezing times are extended considerably when the package contains a significant volume of void spaces. Double contact plate freezers are commonly used for freezing foods in retail packages. This equipment may be batch, semi automatic or automatic. Advantages of this type of equipment include good economy and space utilization, relatively low operating costs compared with other methods, little dehydration of the product and therefore minimum defrosting of condensers, and high rates of heat transfer.

Spray or Immersion freezing

Immersion freezing is a method of commercially preparing frozen foods so that the product remains suitable for consumption over a long period of time. The process helps to lock in moisture as well as maintain the flavor and taste of the processed food. 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. 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. The major advantages of liquid immersion freezing are rapid heat transfer, lower operating and investment costs and easy adaptability to continuous operations. Quick freezing preserves the texture of tissues more successfully and causes less dehydration during the freezing process. However it is difficult to derive freezants with suitable properties.

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. 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. 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 as well as using freon are all other means employed. 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. Further used of refrigerants like freon, though economic is being withdrawn by the industry on account of the concerns with regard to its role in ozone depletion.

Advantages of cryogenic freezing include: improved baseline production rates by reducing the amount of time required to remove heat from a product; marked increase in product yield due to less product dehydration; improved product safety and minimum product degradation due to the short freezing time; better texture retention due to formation of smaller internal ice crystals; low labor costs through reduced product handling and quicker cleanup and consistent production rates.

Crusto Freezing 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.

Quality changes associated with freezing and frozen storage

The quality of frozen-thawed cooked fish is influenced by a number of factors including species, composition, size, harvesting conditions, 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. Reasonable control of toughening and loss of juiciness can be accomplished 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.

Cooling seafoods is among the most effective methods for preserving their quality. From a choice refrigerant, it can be chilling which facilitates short term preservation to freezing at

sub-zero temperatures leading to extended storage life for months and even years, depending on temperature employed. Application of these preservation techniques with standard operating protocols can ensure superior quality seafoods to the customers.

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Seafood Handling and Curing Techniques

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Introduction

Seafoods plays a major role in human nutrition. Fish and shellfish form an important part of the human diet, both of the poor and of the wealthy. Good quality fish is an extremely safe food. The primary objective of seafood handling techniques is to preserve the quality of fish. However, factors such as delay in handling the catch, poor control of fish temperature, poor standards of gutting are often deleterious on the quality of fish and results in reduction of shelf life and loss of weight. Maintaining the quality of fish begins with harvest and transport of the fish products. Since fish is a highly perishable item of food, it is 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.

Hygiene Requirement for Equipment on Fishing Boats

- ✓ Conduct thorough, regular cleaning of the boat and equipment to prevent bacterial build up.
- ✓ Cleaning with clean water and detergent should be done just before and immediately after each fishing trip.
- ✓ All equipment used for handling should be constructed from smooth, easy to clean materials
- ✓ Clean all equipment and fishing gear thoroughly after each operation
- ✓ Allow to dry in the sun and store in clean and dry place

Good handling practices on fishing boats

It is advisable for the fisher-folk to carefully handle their fish products on canoe/boat during transport. This will allow the fisher-folk to maintain high quality of the fish product. There are several factors affecting fish handling on canoe/boat, mostly the biological, chemical and physical factors that cause degradation of fish products. The surfaces of dead fish are ideal growth habitats for bacteria contributing to the spoilage process. Hence, it is important for the fisher-folk to control the temperature of fish. Bacteria growth implicates chemical breakdown due to oxidative and enzymatic reactions leading to off odour; flavor and rancidity. Good handling practices on fishing boats are listed below;

- ✓ Clean seawater should be used to clean boats and equipment.
- ✓ Do not use water that may be contaminated with sewage;
- ✓ Ensure that all fishers maintain a high standard of personal hygiene;
- ✓ Hands and other exposed body parts should be thoroughly washed before handling the catch;
- ✓ Cover cuts and wounds with waterproof plasters;
- ✓ Wash hands with soap and clean water after going to the toilet;
- ✓ Do not cough or sneeze on seafood or ice;
- ✓ Use only good quality ice, made of potable water by an approved supplier

- ✓ Always store ice in clean containers.
- ✓ Avoid large and sharp-edged pieces of ice which can damage the fish;
- ✓ Ice the fish immediately after capture
- ✓ Use at least 1kg of ice to preserve 1 kg of seafood;
- ✓ Ice and seafood should be placed in layers in an insulated container;
- ✓ Ensure proper drainage of melted ice water from boxes;
- ✓ Sort the catch as early as possible in order to protect seafood on the fishing boat from sun and wind.
- ✓ Fish caught at different time, have to be kept apart since they will be at different stage of spoilage
- ✓ Small fishes have to be kept separate from large fishes, as they tend to spoil more rapidly than the latter
- ✓ Soft-bellied fishes are to be kept separately, if the guts are being removed or the belly has burst, the body cavity has to be washed to remove any traces of the gut.

Hygiene requirements for landing sites

- ✓ Landing sites should be washed with safe water and detergents at least once a day;
- ✓ Waste products should be stored in covered containers and disposed of hygienically;
- ✓ Seafood contact surfaces should be free of all type of contaminants like oil, grease, etc;
- ✓ Cutting, cleaning and processing seafood should be done in areas designed for that purpose;
- ✓ Seafood should be stored with ice in clean plastic containers to reduce spoilage and contamination;
- ✓ Landing sites should be fenced and unauthorized access forbidden;
- ✓ Clean and safe water must be available for cleaning the site and equipment;
- ✓ Hand washing facilities, clean water and soap should be present;

Handling of seafood at Landing Sites

- ✓ All boat workers who handle the fish at the landing site should practise good personal hygiene;
- ✓ Persons suffering from contagious diseases should not enter the landing site
- ✓ Chilling should be commenced as soon as possible;
- ✓ Handling should not cause physical damage;
- ✓ Handlers should avoid eating, drinking, using tobacco, chewing gum in production areas, and sneezing and coughing over unprotected food;
- ✓ Seafood handlers should wash and sanitize their hands at the start of food handling activities and immediately after using the toilet;
- ✓ Before handling any seafood, wristwatches, necklaces, rings or other jewellery should be removed. This will reduce the potential for physical contamination.

Hygiene Requirements for seafood during Transport

- ✓ Seafood storage rooms containers / compartments must be designed to avoid contamination of fish and spoilage
- ✓ Containers / compartments must be insulated, and lined with strong, smooth, easy to clean materials;

- ✓ Storage containers / compartments must be closable to keep the seafood at a low temperature during transport;
- ✓ The weight of ice should be equal to the weight of seafood being transported;
- ✓ Seafood should be handled carefully to avoid being damaged;
- ✓ Transporters should be washed with clean water and approved detergents;
- ✓ Transporters must only be used for the transport of fish;
- ✓ Seafood temperatures should be recorded at the start, during, and at the end of transport.

Good fish processing practices : Good fish processing practices refers to appropriate skills and knowledge being used by the fisher-folk and fish processors in processing fish products after harvesting. Hence good fish processing ensure a higher quality fish products. The required condition for good fish processing includes the followings:

- ✓ Fish should be washed in clean water thoroughly to remove blood, slime and scales;
- ✓ Fish are sorted/graded accordingly, large fish are separated from small fish;
- ✓ Fish processing should be done in a proper place where there is no chance for bacteria growth;
- ✓ Equipment and utensils used for fish processing should be kept clean in good condition;
- ✓ Waste fish products should be kept in a closed place that does not allow flies, rats and other pests to breed and be a nuisance;
- ✓ Any waste products from processing must be disposed of in way which does not harm the environment either the water or land;
- ✓ Finished products must be packaged and handled in a careful way to avoid contamination and so they remain safe to eat

Good practices in fish processing area: Specific procedures must be followed to minimize the risk of such hazards causing illness to consumers:

- ✓ The processing area should be closed: have a compound wall and gate to prevent the entry of wandering animals to the premises;
- ✓ Clean the processing area regularly to ensure that there is no rubbish lying around attracting flies, rats and other pests;
- ✓ Use clean equipment and utensils at the fish processing area;
- ✓ The processing area should have a separate washing facility for utensil ;
- ✓ Floor and walls of the peeling shed should be tiled to enable easy washing;
- ✓ The processing area should have a raised receiving area for the unloading of fish products;
- ✓ Make sure that there are good toilet facilities and these are kept clean;
- ✓ Ensure that there are no trees or vegetation near the processing place as these are good places for insects and vermin to live

Curing Techniques

Curing is a process by which the fish is preserved by sun drying, salting, smoking, artificial drying etc. This can be done either by any single method or a combination of these methods. Simple sun drying was the widely practiced traditional method of fish preservation. By this, preservation was achieved by removing the water 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

Drying

Drying is the removal of water from fish, and like salting, is a very common method of preserving fish, particularly in tropical countries. When sufficient water has been removed fish will be preserved because water is essential for bacteria and enzymes to survive and work to spoil fish. Drying is often used in combination with salting and or smoking for additional preservation.

Drying of fish takes place in two phases:

1. Initially, water on or near the surface of the fish evaporates. The rate of drying depends on: i) surface area of the fish (size), ii) speed of air movement over the fish, iii) relative humidity of the air.
2. The second phase occurs when the surface of the fish has evaporated. The drying rate in this phase depends on: i) the nature of the fish. Fat in fish flesh retards water movement; ii) fish shape. The thicker the fish, the longer the time of drying; iii) temperature. Drying will proceed more rapidly at higher temperatures; iv) water content. The higher the water content, the longer the time of drying

Methods of Drying

Drying of fish is most often done using sun drying or mechanical dryers. 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. These can be broadly classified into two types. In one type, the heat is transferred into the product through a hot gas, usually air. Eg. Kiln dryers, cabinet dryers, tunnel dryers and fluidized bed dryers. In the second type, the heat is transferred into the product through a solid surface, which may also be used as the cabinet for the product to be dried. Eg. drum dryer, vacuum dryer

Signs of spoilage in dried fish

1.**Case hardening**: The fish has a chalk-white appearance, and is hard and brittle. This is caused by over-rapid drying, which leads to drying out of the outside of the fish while the inside is still moist.

2. **Mould growth**: The growth of black, blue and green moulds on dried fish is evident. This is due to the high moisture content of the fish either because it was not dried properly or, because it took up moisture from the air and became sufficiently wet to let mould grow.

3. **Reddening**: As with spoiled salted fish, reddening may also occur in spoiled dried fish. Reddening is caused by the red halophiles (salt-loving bacteria) which grow on the dried fish when impure salt contaminated with these bacteria is used

Prevention of spoilage in dried fish

In order to prevent spoilage, care and attention must be used during

1. **Processing**: The fish used must be fresh, prepared correctly according to size, and dried under the required climatic conditions. Using drying racks above the ground will protect against pests.
2. **Transport**: When the fish has dried, it can be packaged into clean plastic bags, or dry secured banana leaves and transported. If the fish is to be sold, it can be displayed inside rat-and-insect-proof boxes, covered with mosquito netting and placed on a table. In this way, the product can be viewed by customers, without being handled.
3. **Storage:** The dried fish must be stored in a place that is free of insects and rodents. The best type of store house is raised on stilts above the ground, in a well-ventilated, shady spot.

Salting

Salting is one of the oldest techniques for preserving fish, and it is a traditional processing method in many parts of the world. Salting is a simple method of fish preservation. Often, salting is used in combination with drying and smoking. However, if the salting process is carried out incorrectly, due to the use of poor-quality starting materials, that is, stale fish, or, the addition of insufficient salt, the product can spoil and will be lost.

How does salt preserve fish?

Salt is a valuable agent in helping to prevent spoilage. Salt preserves by extracting water. This is called dehydration (drying), and happens because water from inside the fish is drawn out into the strong salt solution outside the fish. As the water moves out, the salt moves in, penetrating deep into the flesh of the fish. Water is essential for bacteria (germs) to grow, so if the water is removed, bacteria cannot grow. Furthermore, the spoilage bacteria do not like salty conditions. The more salt in the fish, the more they dislike it. It is important to use clean, dry salt for preserving fish. Dirty salt should not be used and if the salt is wet, it must first be dried. There are some special bacteria that like to live in salt-- these are called the salt-loving bacteria or halophiles. They require salty conditions to grow and can easily be identified in salt because of their pink or red colour. These specialised bacteria can spoil fish, producing unpleasant smells.

Indian Standard Specification for Common Salt for Fish Curing

Physical properties - The material shall be crystalline, white, pale pink or light grey in colour, free from visible contamination with clay, grit and other extraneous adulterants and impurities.

Microbial quality: Salt shall be free from halophilic microorganisms, the most common of them being the red halophilic bacteria.

Particle Size: The material shall be between 2.36 mm and 5.00 mm in size.

Moisture Content: The moisture content of the material shall be not more than 6.0 percent by mass

Table 1: Requirements of common salt for fish curing

Sl.No	Characteristics	Grade 1	Grade 2
1.	Matter ,insolublc in water, percent by mass, &lax	0.5	1.0
2.	Sodium chloride (as NaCl), percent by mass, Min	98	96
3.	Calcium and magnesium (as Ca) percent by mass, Max	0.5	-
4.	Soluble iron compounds (as Fe), parts per million, Max	10	20
5.	Matter soluble in water other than NaCl, percent by mass, Max	1.5	3.0
6.	Copper (as Cu), parts per million, Max	1	1

Salting methods

There are two methods of salting fish-- wet salting and dry salting.

Wet salting: The principle of wet salting is to keep the fish for a long time in a solution of salt and water, otherwise known as 'brine'. Brining and pickle curing are the two methods used for wet salting. Which method is used depends on whether the product will be further processed by drying or smoking, or just preserved with salting. Brining requires the water used to be saturated with salt. To make the brine, mix four parts of clean water and one part of salt (for example, 10 litres (2 gallons) of clean, fresh water to 2.7 kg-3.6 kg (6-8lbs of dry salt) in a clean, large plastic drum. Keep adding salt to the water, until no more salt will dissolve.

The next step depends on what kind of fish you want to salt. If the fish is large, it is best to cut off the head, and gut and clean the fish before soaking it in the brine. Large fish must be cut open, and it is preferable to take out the backbone. Fish which are covered in a heavy coating of scales must be scaled. In places where the flesh is thick, slashes must be made so that the salted brine can penetrate the flesh. Very large fish should be cut into thin fillets. If the fish is small, it can be soaked after it has been gutted and gilled. After the fish has been prepared according to its size, it must be cleaned and put in the brine. Stir the mixture every 20 to 30 minutes. Brining will take as little time as 30 minutes for light salting, or up to 24 hours for medium salting. Fish for drying, smoking and canning are usually brined prior to processing.

Dry salting or Kench curing: In this method the fish is salted, but the juices, and brine (pickle) are allowed to drain away. For 2 parts of fish, 1 part of salt is needed. Layers of fish are separated by layers of salt and placed into a wooden box that has slats cut out of the sides, enabling the draining of juice. It is important to layer the fish with the first layer being flesh-side upwards, and the next layer of fish being flesh-side down. The final layer should be salt. The box has a lid placed on top of the stack and weighted to press the fish down. This encourages faster salt penetration and water removal. Salting time varies from three days to a week, depending on the type and size of fish. This method cannot be recommended for general use in the tropics as the fish are not covered by the brine or pickle and are therefore more susceptible to spoilage and insect attack. Exposure to the air and the presence of salt also encourages the rate of fat oxidation which gives rise to discoloration and the characteristic rancid flavours. Recommended fish are barracuda, parrotfish, snapper and shark.

In dry salting, the size of salt crystals is important. Fine crystals tend to dissolve too quickly and are dragged down and drained, whereas large crystals dissolve very slowly and there is a risk of deterioration. Fine crystals and larger crystals should be combined. The fine crystals will dissolve quickly and salt will penetrate the flesh immediately. The large ones will dissolve slowly to maintain the salt's action during the whole time of salting. To store dry salted fish, first brush off all excess salt, and place fish neatly in a strong plastic bag. Seal the bag, and keep it somewhere cool, and away from sunlight. The fish should be inspected at regular intervals. If there has been a period of damp weather, and the dried fish show signs of moisture, they should be given a few hours of air drying. If signs of rust and mold appear, the fish should be scrubbed in a light salt brine containing some vinegar, then spread out to dry in the air for a day or two. The product should last for many months.

Pickle salting: Pickle curing is a type of wet salting where the fish is layered by granular salt (fish-to-salt ratio of 1-part fish to 0.3 or 0.4 parts salt by weight) which, dissolves in the surface moisture of the fish forming solution which penetrates into the fish removing moisture from the fish. The fish is allowed to remain in this self-brine. If the self-brine is not sufficient, saturated brine is added to immerse the fish. For salting, keep the fish in to flesh to flesh and skin to skin form. After each layer of fish sprinkle on a thin layer of salt. Make sure you finish with a layer of fish, skin upwards, and a final layer of salt. Water from the fish will quickly

start to form. The surrounding salt will dissolve in this water. This is called the pickle. It is retained inside the container and will eventually cover all the fish. Place a clean piece of wood weighed down with clean stones on the top of the fish until salting is completed. This will take 36 to 40 hours for small, whole fish and three to four days for large pieces of fish. Wet salted fish should be consumed within 2 months of storage at an ambient temperature. It will keep for several months if stored in a cool place.

Mona curing: Mona curing is mainly adopted for medium to small size fishes. Before salting, the intestine and entrails are removed by pulling out through the gill region without split opening the fish. The flesh is not exposed during salting thereby causing less contamination and the product has a shelf stability of about two months. The yield obtained by this method is about 70%.

Pit curing: In this method, fish is mixed with salt (4:1) and placed in pits dug on beaches. The pits may be lined with palymrah / coconut leaves. After 2-3 days of maturation, the fish is taken out for marketing in wet condition and packed in bamboo baskets and transported to markets without drying. The quality of fish cured by this technique is poor with a shelf stability of upto three weeks only.

Colombo Curing: Colombo curing is similar to pickling process which is widely practiced in Sri Lanka. A piece of dried Malabar tamarind (*Garginia cambogea*) is kept in the abdomen portion of the gutted and cleaned fish which is further stacked in airtight wooden barrels filled with brine. Fishes cured by this method has a shelf life for upto 6 months.

Signs of spoilage in salted fish

1. **Reddening or pink**: The fish takes on a red colouring. This is caused by red halophilic bacteria. These organisms are usually found in solar salt.

2. **Dun**: Dun is characterised by a peppering of light brown or fawn spots on the fish. This is mainly caused by growth of halophilic mould called *Sporendonema epizoum*. During the initial stages of appearance of moulds on the fish, it is possible to remove them manually. In advanced stages it penetrates into the flesh. To avoid the mould growth, it is necessary that the fish be dried, packed and stored properly to avoid uptake of moisture. It is caused by the use of impure salt and unsanitary practices during preparation.

3. **Souring**: Fish which has soured has a bitter taste. Souring is due to improper salting which results in the uneven distribution of salt throughout the muscles of the fish.

4. Salt burn: The fish is extremely dry and cannot be rehydrated. This happens when too much fine salt has been used. This salt draws out the surface moisture so rapidly that protein in the fish becomes solid, which stops the fish from taking in water later on. A mixture of large and small grain sizes is recommended for dry salting of fish

5. Sliming: The surface of the fish acquires a slippery coating of slime. This usually occurs in brined fish because of inadequate salting, lack of freshness of fish, and other factors.

6. Case hardening: Under certain conditions, where the constant rate drying is very rapid due to high temperature and low relative humidity, the surface of the fish can become 'case hardened' and the movement of moisture from the deeper layers to the surface is prevented. This can result in a fish which is dry at surface. However, the centre remains wet and hence spoils quickly.

7. Rancidity: This is caused by the oxidation of fat, which is more pronounced in oil rich fishes like mackerel, sardine etc. The unsaturated fat in the fish reacts with the oxygen in the atmosphere forming peroxides, which are further broken down into simple and odoriferous compounds like aldehydes, ketones and hydroxyl acids, which impart the characteristic odors. At this stage the colour of the fish changes from yellowish to brown referred to as rust. This change results in an unpleasant flavour and odour to the product, leading to consumer rejection.

8. Insect Infestation: Spoilage due to insect infestation occurs during initial drying stages as well as during storage of the dried samples. The flies which attack the fish during the initial drying stage are mainly blowflies belonging to the family Calliphoridae and Sarcophagidae. These flies are attracted by the smell of decaying matter and odours emitted from the deteriorating fishes. During the glut season when the fish is in plenty and some are left to rot, these flies come and lay their eggs. These eggs develop into maggots, which bury within the gill region and sand for protection from extreme heat. and develop mainly when conditions are favourable. The most commonly found pests during storage are beetles belonging to the family Dermestidae. The commonly found beetles are *Dermestes ater*, *D. frischii* and *D. maculates*

9. Fragmentation: Denaturation and excess drying of fish results in breaking down of the fish during handling. Fish can become brittle and liable to physical damage when handled roughly. Insect infestation is also a reason behind fragmentation in dried samples. It is necessary that fresh fish be used as raw material to ensure a good finished product.

Prevention of spoilage in cured fish products

Raw material

- ✓ Fish must be as fresh as possible. Fatty fish is best wet salted, while lean fish is best dry salted. Take care not to damage fish during handling.
- ✓ Salt must be clean and dry. Note: mix of 1/3 small crystals:2/3 large crystals for dry salting. Fine crystals are usually better for wet salting
- ✓ Use clean water

Processing methods

- ✓ Ensure that hands, clothing, cooking utensils and work surfaces are perfectly clean.
- ✓ Take note of the time required for each step of the salting process.
- ✓ Pay attention to the amount of salt or brine/fish weight ratio.
- ✓ Containers must be clean, and possess a secure lid.

Handling of finished products

- ✓ Dry salted fish can be enclosed in clean/dry plastic bags or wrapped and secured inside dry banana leaves.
- ✓ The salted fish must be stored in a clean, and if possible, cool place. Keep it away from dust, insects, rodents and direct sunshine. Not only is it important to obtain a good product, but it is also important to keep it in good condition.

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Thermal and Non-thermal processing of fishes

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Introduction

'Thermal processing' or 'preservation by heat' is a widely used method for storage life enhancement of food due to its high safety level and convenience. The basic purpose of thermal processing of foods is to reduce or destroy microbial activity, reduce or destroy enzyme activity and produce physical or chemical changes to make the food meet a certain quality standard. e.g., gelatinization of starch & denaturation of proteins to produce edible food. Thermal processing is generally referred to as canning, which helps in realizing 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. But there are a number of heat processing methods employed by the food industry. Mild processes are Blanching and Pasteurisation. More severe processes include Canning, Baking, Roasting and Frying.

Blanching

Blanching is a mild heat treatment, which primarily destroys enzymes and also reduces microbial load. It is not intended as a sole method of preservation, but as a pre-treatment prior to freezing, drying and canning. Blanching is carried out at up to 100 °C using hot water or steam at or near atmospheric pressure. Microwave is also used for blanching, which has the advantages such as rapid heating and reduced loss of water-soluble components.

Pasteurization

Pasteurization is a relatively mild heat treatment in which food is heated to <100°C. This can be used to destroy enzymes and relatively heat-sensitive microorganisms. Pasteurization is intended to inactivate vegetative cells not the spores of all pathogenic bacteria and is used to extend the shelf life of food by several days, e.g., milk. There are different methods of pasteurization such as low-temperature long time, LTLT/batch/holding method (63°C for 30 min), high-temperature short time, HTST/flash method (72°C For 15 sec) and ultra-heat treatment (UHT) at higher temperatures and shorter times, e.g., 1 s at 135 °C.

Sterilization/Canning

Sterilization is heat processing at high temperatures (above 100 °C) with the objective of destroying all forms of microorganisms including spores. Canning is a method that sterilizes food by heat in airtight containers to achieve a commercially sterilized product. This allows food to be stored at room temperature while maintaining food safety and organoleptic quality for months or even years. It is invented by the Frenchman Nicholas Appert and is sometimes referred to as 'appertization'. There are two typical forms of canning: in-container sterilization (i.e., retort processing) and out-of-container sterilization (i.e., aseptic processing).

Classification of foods based on pH

From a thermal-processing standpoint, foods are divided into three distinct pH groups, which are given below.

1. High-acid foods (pH < 3.7)
2. Acid or Medium-acid foods (pH 3.7 - 4.5)
3. Low-acid foods (pH > 4.5).

Canned seafoods are characterized by a pH > 4.6 and aw > 0.98.

Clostridium botulinum

Foods with a pH greater than 4.6 are called 'low acid canned foods' (LACF), for which the micro-organism of major concern is *Clostridium botulinum*. *C. botulinum* is a highly heat resistant mesophilic, Gram-positive, rod-shaped spore-forming anaerobic pathogen, which produces the toxin botulin. It has been generally accepted that *C. botulinum* and other spore-forming human pathogens do not grow and produce toxins below a pH of 4.6. Growth of *C. botulinum* is a risk in low-acid foods having a pH above 4.6 including fishery products, where it is necessary to apply a time–temperature regime sufficient to inactivate spores of *C. botulinum*.

Botulinum cook or the 12D concept

Experience has shown that the minimum heat process necessary to preserve low-acid canned foods (LACF) should enable the reduction of the most heat-resistant *C. botulinum* spores to 10^{-12} of its initial count. This is known as the botulinum cook or the 12D concept.

D value/Decimal reduction time/Thermal reduction time

The D value is the time required to reduce the number of spores of *C. botulinum* (or any other micro-organism) by a factor of 10 at a specific reference temperature (121.1°C) or it is the time necessary to inactivate 90 % of a given microbial population by heating at a constant temperature. The unit of measurement for D is 'minute'. The D value for bacterial spores is independent of initial numbers, but it is affected by the temperature of the heating medium. The higher the temperature, the faster the rate of thermal destruction and the lower the D value. A thermal process based on the 12D concept should achieve a probability of survival of one spore in one of one trillion containers. In other words, the probability of one container being non-sterile is equal to 10^{-12}, i.e., one can in one trillion cans is not sterile.

The thermal death time (TDT)

TDT is the heating time required to cause complete destruction of a microbial population. It may be defined as the time required at any specified temperature to inactivate an arbitrarily chosen proportion of the spores. TDT value depends on the initial microbial load (while D value does not). TDT is always measured with reference to a standard initial load or load reduction, it simply represents a certain multiple of D value. For example, if TDT represents the time to reduce the population from 10^{0} to 10^{-12}, then TDT is a measure of 12 D values. i.e., TDT = nD, where n is the number of decimal reductions. The extent of inactivation in the case of pathogenic microorganisms (*C. botulinum*) is equivalent to a 12 D process. For the purpose of heat process determination with respect to their lethality towards specific micro-

organisms, the reciprocal of the thermal death time (TDT value) called the lethal rate, L is used.

'z' value

The slope of the TDT curve is defined as 'z' value, which is the number of degrees for the TDT curve to traverse one log cycle. The 'z' value is also known as the temperature sensitivity indicator. It represents a temperature range resulting in a ten-fold change in D values or, on a semi log graph, it represents the temperature range between which the D value curve passes through one logarithmic cycle. The 'z' value is usually taken as 10 °C in the case of *C. botulinum*.

F_o value

Thermal processes are calibrated in terms of the equivalent time the thermal centre of the product, i.e., the point of the product in the container most distant from the heat source or cold spot, spends at 121.1 °C. This thermal process lethality time is termed as process value or F_0 value. F_0 is the sterilization process equivalent time, defined as the number of equivalent minutes at T = 121.1 ºC delivered to a food container calculated using Z value (the temperature increase required for a tenfold decrease in the D value) of 10 ºC. Lower F_os yield microbially safe and shelf-stable products without undue impairment of flavour, consistency, colour or nutrient content.

Commercial sterility

Commercial sterility is the condition achieved by the application of heat, sufficient alone or in combination with other appropriate treatments, to render the food free from microorganisms capable of growing in the food at normal non-refrigerated conditions at which the food is likely to be held during distribution and storage (FAO/WHO Codex Alimentarius Commission, 1983). Canning of food for preservation requires the use of a hermetically sealed container, which is impermeable to liquids, gases and micro-organisms, and the use of a heat process sufficient to inactivate micro-organisms capable of proliferating under normal non-refrigerated conditions of storage and distribution. Any canned food that meets these two requirements is considered 'commercially sterile'. Commercial sterility is different from 'absolute sterility'. The latter means total absence of viable micro-organisms, whereas viable micro-organisms can be recovered from commercially sterile canned fish.

Containers for thermal processing/ Packaging Materials

- Tin plate
- Tin-free steel (TFS)
- Aluminium alloys
- Retort pouch
- Glass containers

Metal containers are normally divided into two groups:

- 2-piece cans (Cylindrical, square, flat rectangular, oval or round)

- 3-piece cans with soldered or welded body. They are generally cylindrical with two lids attached to the cylindrical body by double seaming.

Historically, heat processing started in glass containers. Over the years, different containers like metal, rigid plastic containers and flexible retortable pouches have been developed for thermal processing. The most common material used for manufacturing containers for fish products are tin plate, aluminium and lacquered steel plate (TFS). Enamel coatings are used to protect tin plate, aluminium alloys and TFS. Flexible packaging as an alternative to metal cans has become more common during the last years and glass jars are sometimes used for speciality packs. Nowadays, retort pouch processing is very popular.

Retort pouches

The most common retort pouch is 3-layered laminate. The 3 layers are joined with adhesive lamination. These three layers are; Polyester layer which helps in providing strength and abrasion resistance, Aluminium foil for providing barrier against moisture, gases and light and Polypropylene/ polyethylene for heat sealing properties.

Thermally Processed Fishery Products

Fishery products, being categorized as low-acid foods require heat processing severity with respect to *C. botulinum*. These products have to be processed in such a way that all the points in the container should achieve a minimum lethality of 2.52 minutes, when processed at 121.1 ^{o}C (250 ^{o}F), which corresponds to 12 decimal reduction of *C. botulinum*. In practice, fish products are processed beyond this lethality for safety reasons. The selection of prime-quality fish is important for heat processing. Thermal processing of various ready-to-eat fish products has been studied and reported by ICAR-CIFT, Kochi. Mohan et al. (2015) studied the effect of filling medium on cooking time and quality of canned yellowfin tuna (*Thunnus albacares*).

Steps in fish canning

The important steps in canning process are:

1. Raw material selection and preparation
2. Blanching/ Precooking
3. Filling into containers
4. Addition of fill (brine/ oil/ gravy)
5. Exhausting
6. Seaming/ sealing
7. Retorting (heat processing)
8. Cooling
9. Drying
10. Labelling and storage

Hazards in fish canning

- Survival of pathogens during heat processing
- Presence of heat-stable toxins (biotoxins, histamine) in the raw material

- Recontamination of product after heat processing (faulty containers, poor sealing, contaminated cooling-water, faulty container handling).

Retort pouch processing

As in canning, retort pouch food is sterilized after packing, but the sterilization procedure differs. The pouches are processed in an over-pressure retort. The time and temperature will be standardized depending on the product. Besides, cost reduction, retort pouch packages have unique advantages like boil-in-bag facility, ease of opening, reduced weight and don't require refrigeration for storage. The energy saving is more in processing in flexible pouches compared to cans. Processed food products can be kept for long periods at ambient temperatures. Bindu et al. (2007) reported that ready-to-eat black clam (*Villorita cyprinoides*) product in indigenous retort pouches remained in good condition even after storage for one year at ambient temperature (28 ± 2 °C).

Non-thermal Processing Techniques

The demand from consumers for safe and nutritious food products has promoted the rapid development of non- thermal processing technologies. Non-thermal food processing simply refers to methods where the food materials receive microbiological inactivation without the direct application of heat. They are relatively young technologies, which use mechanisms other than conventional heating to reduce or eliminate microorganisms.

1. High-pressure processing

High-Pressure Processing is also known as high hydrostatic pressure (HHP) or ultra-high pressure (UHL) processing. It is a non-thermal, cold pasteurization technique, which generally consists of subjecting food, previously sealed in flexible and water-resistant packaging, to a high level of hydrostatic pressure (pressure transmitted by water) up to 600 MPa / 87,000 psi for a few seconds to a few minutes (1 – 20 min). HHP utilizes a very common medium, i.e., water, to apply the pressure on the product to be treated. HHP transmits isostatic pressure (100–1000 MPa) instantly to product at low temperature and might have comparable preservation effect as thermal processing through inactivating undesirable microorganisms and enzymes. An HPP unit consists of a pressure compartment in which food is kept and water is introduced into the chamber. Food is then pressurized using this water. HPP compromises cellular functions such as DNA replication, transcription, translation already at lower pressures (≤100 MPa) which impairs bacterial growth. At higher pressures, microorganisms start suffering lethal injuries due to loss of cell membrane integrity and protein functionality. The most sensitive to pressures are moulds, yeast and parasites.

Studies at ICAR-CIFT, Kochi

Ginson et. al. (2015) studied the effect of high-pressure treatment (250 MPa for 6 min at 25 °C) on microbiological quality of Indian white prawn (*Fenneropenaeus indicus*) during chilled storage. All microbes were reduced significantly after high pressure treatment and there was significant difference in microbial quality of control and high pressure treated samples in the entire duration of chilled storage. Kunnath et. al. (2020) reported that synergistic effect of high pressure and microbial transglutaminase (MTGase) could enhance

the textural and functional properties of fish gels, when compared with conventional cooking. MTGase enzyme along with pressure treatment enhanced the conformational stability and produce stronger networks through the formation of non sulfide bonds between proteins and setting reinforced these networks. Devatkal et. al. (2015) employed high-pressure processing (300 MPa for 5 min) as a non-thermal post-processing intervention to improve the shelf life and quality of cooked refrigerated chicken nuggets. Kundukulangara Pulissery et. al. (2021) compared the textural and nutritional profile of high pressure and minimally processed pineapple. On the basis of microbial quality and sensory assessment, high pressure treatment at 300 MPa for 10 min was found to be suitable for preserving the quality of pineapple up to 16^{th} day in refrigeration condition. Ginson et. al. (2020) investigated the piezotolerance and diversity indices of microflora of Indian white prawn (Fenneropenaeus indicus) after high pressure (HP)-treatment. *Arthrobacter spp., Listeria grayi* and *Corynebacterium spp*. were the most piezo tolerant bacteria in HP-treated samples.

2. Pulsed electric field (PEF) processing

PEF is an efficient non-thermal food processing technique using short, high voltage pulses. It is used for inactivation of spoilage and pathogenic microorganisms in various food products. Electric pulses are applied for destroying harmful bacteria in food. Microbial inactivation is achieved by dielectric breakdown of the bacterial membranes. Food material is placed between electrodes. The field intensity is typically 20–80 kV cm^{-1}) and the exposure time is a few milliseconds or nanoseconds. It enhances the shelf life of the food without quality loss. The PEF mechanism is called ***electroporation***. Very short electric pulses of high voltage are applied to the food. Small pores are formed in the cell membrane of the food by the electric pulses without damaging the cell compounds, such as vitamins. Pulsed electric field is generally used for liquid food or semi-solid food that can flow easily.

3. Irradiation/Radiation processing

Irradiation refers to the process by which an object is exposed to radiation (A deliberate exposure to radiation). There are two forms of radiation: Ionizing radiation (IR) and non-ionizing radiation (NIR). IR includes high-energy electron beam, X-rays and γ-rays. IR leads to the production of charged particles or ions in material it comes in contacts with. Irradiation is a process of applying low levels of ionizing radiation to food material to sterilize or extend its shelf life. Radiation inactivates food spoilage organisms, including bacteria, moulds, and yeasts. It is effective in lengthening the shelf-life of fresh fruits and vegetables by controlling the normal biological changes associated with ripening, maturation, sprouting, and finally aging. Radiation also destroys disease-causing organisms, including parasitic worms and insect pests, that damage food in storage. Irradiation is harmful or noxious to humans. However, the dose for seafood pre-treatment is low, therefore making it safe for consumption. Food irradiated under approved conditions does not become radioactive.

Studies at ICAR-CIFT, Kochi

Annamalai et. al. (2020) assessed the effect of electron beam irradiation ((0, 2.5, 5.0, 7.5 and 10 kGy) on the biochemical, microbiological and sensory quality of vacuum packed headless

Litopenaeus vannamei during chilled storage (2 °C). There is a significant ($p<0.05$) reduction in *Brochothrix thermosphacta* and *lactobacillus* count in the irradiated sample. Based on the microbial and sensory analysis control had a shelf life up to 12th day. However, electron beam irradiated sample had an extended shelf life of 15-23 days with respect to dose level.

4. Ultraviolet (UV) Radiation

UV radiation is a form of energy considered to be non-ionizing radiation having in general germicidal properties at wavelengths in the range of 200–280 nm (usually termed UV-C). UV irradiation has demonstrated to be effective not only in reducing microbial load but also inactivating enzymes activity in plant products. When food is exposed to UV-C, with 200–280 nm, these short wavelengths are absorbed by the microbial cell nucleic acids. These absorbed photons cause the breakage of the bond and interlinking between thymine and pyrimidine of different strands and the formation of dimers of pyrimidine. These dimers (Photo products) prevent DNA transcription and translation, thus leading to the malfunctioning of the genetic material, which causes microbial cell death. In principle, the UV radiation operates by destroying the genetic constituent of the pathogen to prevent division, multiplication and subsequently hinder its propagation. Usually, different kinds of food products require different doses of UV radiation (termed as UV-inactivation dose measured in mJ/cm^2) to inactivate different kinds of pathogens.

5. Pulsed Light (PL) Preservation

Pulsed light (PL) is an alternative technique to continuous ultraviolet treatment for solid and liquid foods. PL consists of successive repetition of high-power pulses of light/short time high-peak pulses of broad-spectrum white light. Comparatively, PL has a thousand times strength greater than the normal UV light which is quite continuous. Pulsed xenon UV uses the full spectrum of ultraviolet light to disperse germ-killing energy. The light spectrum includes wavelengths from 180 to 1100 nm with a considerable amount of light in the short-wave UV spectrum. Similar to other non-thermal food processing technologies, PL also has potential in the inactivation or elimination of microbes in food. Specific examples of foods processed by PL include fish, vegetables, fruits, and meat. PL can be used alongside other novel technologies as a hurdle in the inactivation of microbes on the surfaces of foods.

Studies at ICAR-CIFT, Kochi

Ananthanarayanan et. al. (2019) studied the effect of pulsed light (PL) treatment on the shelf-life extension of yellowfin tuna (*Thunnus albacares*) steaks stored at 2±1 ^{o}C. Tuna steaks of 1 cm thickness weighing 80 g packed in 300-gauge cast polypropylene pouches were subjected to PL treatment using Xenon pulse light machine RC-847. Shelf-life studies were carried out in terms of reduction of aerobic flora as inferred from the total plate count (TPC) and the psychrophilic count. An overall extension of 13 days of shelf life was achieved for PL treated samples.

6. Ultrasound (US) processing

US is a compressional wave with a frequency of over 20 kHz. Sound wave bearing certain frequency that is more than the normal human hearing frequency. The frequency of US used

in the food industry for microbial inactivation ranges from 20 kHz to 10 MHz. The bactericidal action of US is mainly due to the cavitation process, in which microbubbles are produced and collapsed within a liquid medium. During the cavitation process, the temperature can increase to as high as 5500 °C and the pressure can increase up to 100 MPa, resulting in localized microbial sterilization. The bactericidal mechanisms of ultrasound include breakage of cell walls, disruption and thinning of cell membranes and free radical activity due to the collapse of cavitation bubbles.

7. Cold Plasma (CP) Technology

Ionization of gas molecules gives rise to plasma. Cold plasma is a non-thermal treatment that works in the temperature range 25–65 ^{o}C. Cold plasma has high antimicrobial activity and efficient enzyme inactivation capacity. The composition of the plasma reactive species largely depends on the composition of gas which is ionized. The gases commonly used for the generation of plasma include argon, helium, oxygen, nitrogen and air. The gases are subjected to any of the types of energy like thermal, electrical, magnetic field, etc., to generate plasma containing positive ions, negative ions, and reactive species like ozone and singlet oxygen.

8. Ozone treatment

Ozone is extensively employed as an effective antibacterial against many bacteria in food. Due to its high oxidizing potential and the ability to attack cellular components, ozone has broad-spectrum of disinfection. Ozone treatment is a chemical method of food decontamination that involves exposing contaminated foodstuffs (fruits, vegetables, beverages, spices, herbs, meat, fish, and so on) to ozone in aqueous and/or gaseous phases. Ozone alters the permeability of cells by damaging the microbial cell membranes. Ozone is also known to damage the structure of proteins, leading to the malfunctioning of microbial enzymes, which affects the metabolic activity and finally results in microbial cell death. Chemical composition, pH, additives, temperature, initial bacteria population, and ozone contact time with food and food surface type are factors determining the efficiency of ozone treatment on microbial reduction in seafoods

Conclusion

Fish require immediate processing and packaging to retain its quality. In addition to the existing fish preservation methods, many advanced processing techniques have been developed over the years to meet the consumer demand of fresh, safe and minimally processed fish. With non-thermal treatments, consumers get high quality, healthy, and safe food products. But there are two sides of the coin: with advantages come some disadvantages as well. If food is exposed for a longer period or treated at a higher intensity, these non-thermal technologies may lead to some undesirable changes in food, such as oxidation of lipids and loss of colour and flavour. But these technologies have many advantages compared to thermal processing. After overcoming the limitations properly in a planned manner, non-thermal technologies will have a broader scope for development and commercialization in food processing industries.

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Value Added Fish Products

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Introduction

Adding value to fishery resources is one of the most prominent approaches in fish processing. The process of value addition increases the market value of low value fish along with the creation of employment opportunities. Furthermore, the export of fish-based value added products is an attractive business for foreign earnings by extending the sale to global markets. The popularity of fish products in the domestic, as well as the international market, is on an increasing trend as there is a rising need for diets rich in protein to substitute high calorie foods. Value addition is a strategy to increase the pace with diversity in terms of market forms. The term value addition is defined as "any additional activity that changes the nature of the product which leads to an increase in price at the time of sale". Value addition is the enhancement added to a product before it is offered to the customers. In other terms, value addition is a process through which a high price is realized for the same volume of the primary product utilizing any kind of processing, packing or upgradation of quality.

Value addition is a profitable strategy to enhance the consumption of fish for nutritional and health benefits. Fish is a superfood for humans because of its rich nutrient reserves such as high-quality protein content, n-3 polyunsaturated fatty acids (PUFAs), minerals, vitamins, and other trace elements. Considering the benefits, it provides it is recommended to consume fish at least two times per week as part of a healthy diet. To increase the popularity of value added fish products across the world, product diversification with international flavors including ethnic flavours are of great importance.

Ways of adding value

According to the market demand the existing products need to be modified over time to catch hold with the new customers and also to compete for the competition in business. The process is dynamic, sensitive, complex and very expensive. The value can be added by improving the market forms, developing convenience food and functional foods. A change in the appearance, display and packaging is also an important aspect for consideration. New product features are to be added to make the product more convenient. In addition, market surveys are to be conducted regularly to update and modify the existing product. Strong linkages to develop the marketing channel and proper advertisement are required to reach the customers. Innovative products with multiple formats or shapes or dimensions, flavours, texture profiles, and new packages will attract customers without any difficulty. The continuous invention, innovation and refinement is essential to stay in the business.

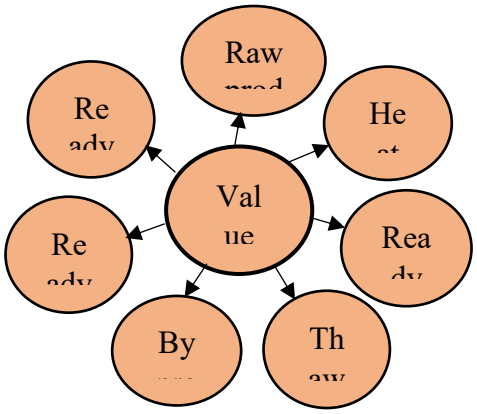
Why value addition is required?

- To increase the productivity

- To enhance the shelf life of the fish
- To improve the safety of the fish based products through processing
- To reduce the wastage and discard of the fishery resources especially the low value and low demand fish species in the market
- To enhances the profitable and judicious utilization of low valued fish
- To fulfil the consumers' demands for convenience foods with quality and longer shelf life
- To diversify the market forms
- To get a better income for the stakeholders
- To promote the nation's economic growth through domestic or international trade of different ready-to-eat or ready to cook or ready to serve products
- To create self-employment opportunities

As fish is a highly perishable commodity preservation by various means is of utmost importance to extend its shelf life. Preservation helps to keep the fresh fish edible for a longer period.

Categories of value added fish products



These products are gaining wide acceptance as modern customers prefer convenience products mostly ready-to-cook foods. Different categories of such value added products from fishery resources are discussed in this chapter.

Raw and processed fish in different product styles

Raw and processed fish are marketed in different appearances, shapes, dimensions, and formats for attracting customers and for increasing the convenience. Chilled and frozen fishes are available in a variety of such product styles in the modern market. Examples of such product styles of finfishes are cleaned whole fish, drawn fish (only the entrails removed), dressed or pan-dressed fish (fins, head, and tail removed), steaks, fillets, sticks, butterfly style (dorso-ventral cut), chunks, cubes, etc. A few examples of the product styles of shellfish include peeled & deveined shrimp, peeled, cooked & tail-on shrimp, headless shrimp, shrimp head on (centre peeled), shrimp head on cooked (centre peeled), barbecue shrimp (beheaded, deveined, peeled with a bamboo stick pierced into the meat from head to tail portion), sushi

(cooked butterfly shrimp), skewered shrimp (4-5 shrimps are arranged in a skewer in an inverted "U" shape), squid tubes, squid rings, live lobster, frozen lobster tails, whole lobster frozen or chilled, whole cooked and frozen lobster meat, whole or shucked molluscs, etc.

Chilled fish products

Chilled fish is an important value added product that dominates the market in terms of revenue. Prime quality chilled fish usually fetch a higher price than frozen fish. Chilling is a low-temperature preservation method in which fish is preserved using ice. It is the most common primary preservation method used for short-term preservation. In this method, the temperature is lowered to 1 to 4°C by packing the fish and ice are in alternative layers in the ratio of 1:1 (1 Kg fish require 1 Kg ice). Lowering the temperature arrest the enzymatic and microbial changes taking place in fish thereby reducing the spoilage rate. Chilling should be done quickly as possible after the harvest of the fish to get high-quality end products. The most common type of ice used is flake ice or crushed block ice.

The shelf life of the fish stored in a chilled condition depends on the shape, size, fat content, and skin characteristics. Round, small fatty fishes with thin skin will spoil faster compared to large, flat, lean fishes with thick skin. Generally, lean fishes will have a shelf life of 12-16 days, fatty fishes 5-8 days, prawns 8-10 days, and cephalopods 4-8 days. The application of modern packaging techniques such as vacuum packaging, modified atmospheric packaging, and active packaging considerably increases the shelf life of chilled fish products. Chilled sashimi grade tuna from bluefin, bigeye, and yellowfin tuna is a major delicacy in the international market. Other than raw fish, chilled processed fish products like smoked and marinated fishes are also available in the market.

Frozen fish products

Frozen fish products are very popular in the trade. Freezing is a modern method intended for the long-term preservation of fish at low temperatures. It is considered as a gentle method as the organoleptic qualities of the properly stored frozen fish is as good as fresh fish. During the process of freezing the water in the fish is converted to ice unlike chilling. The ideal condition for fish to be frozen is –30°C for 2 hours. Further storage at cold storage (-18°C or below) is mandatory. Frozen fish fillets and steaks are popular in domestic markets whereas block frozen fish and individually quick frozen (IQF) fish play a major role in the international markets. In IQF technology, the fish is frozen individually in the highest quality possible. IQF Head on/Headless/Butterfly cooked/Blanched shrimp, IQF tray packed shrimp, IQF peeled tail-on cooked shrimp, IQF marinated shrimp, Skinless & boneless fish fillets, IQF cooked/blanched squid/cuttlefish, Stuffed squid IQF tray packed, IQF tray packed lobster meat, whole cooked lobster, lobster tails, lobster meat, squid tubes, squid rings, fan tail, round tail-on shrimp, stretched shrimp (Nobashi), skewered shrimp, boiled clam meat, etc. are few examples of frozen fish products popular in the market. The expected shelf life of frozen fish is 9 months to 2 years.

Traditional Fish Products

Traditional fish preservation methods are age-old practices used to preserve fish for long term storage. Mostly the methods are region-specific and are used to preserve the catch when available in glut. The methods include drying, salting, smoking, marination, and fermentation. These methods are altogether known as curing methods. All these traditional fish preservation techniques follow centuries-old indigenous knowledge of fish processing. The customer demand for ethnic flavors and cuisines is ever-increasing due to market expansion, globalization and hence they are upgraded as specialty food products. The important ethnic fish products are as follows:

Dry fish products

Dried fish with or without salt is popular in domestic markets as well as in overseas markets. The method of drying is one of the widely used fish preservation techniques in which the moisture content in fish is removed by evaporation to arrest the spoilage caused by the activities of microorganisms and enzymes. This is one of the oldest and cheapest method employed for preservation. Fish drying can be done by natural and artificial means. Natural drying or sun drying is the process in which fishes are dried under sunlight. Here solar energy is used to evaporate the water in fish. In artificial drying, the fish is dried mechanically in an enclosed atmosphere under controlled conditions, unlike natural drying where we have no control over the environmental condition. Drying under controlled condition is known as dehydration. The ideal temperature for fish drying is 44-55°C. There is high demand for spiced and dried products, flavour-incorporated products, coated and dried products in the modern market. Entrepreneurs are attracted to this business as it is highly profitable that requires less sophisticated machinery and storage facilities. The dried products can be stored in dry conditions at ambient temperature for a minimum of six months if properly dried and packed.

Salted fish products

Salting is a method in which common salt (sodium chloride) is used to preserve the fish. It is practiced as such or in combination with drying or smoking. The penetration of salt into the fish tissue removes the water inside, thus reducing the water activity which will help to inhibit spoilage by bacteria. Along with this, enzymes also get inactivated which further delays the spoilage. Generally, small-sized fishes are salted directly without removing the head, fins, and entrails, unlike large and medium-sized fishes. For attaining proper salting and drying, the fish can be cut into butterfly-style, small pieces or scoring can be done to increase the surface area. Layer salting is preferred for medium and large-sized fishes whereas small-sized fishes can be salted by dip treatment for uniform penetration of salt through flesh. Fish to the salt ratio for layer salting is in the range of 2:1 to 10:1 for big to small-sized fishes. Dip treatment can be done for 5-10 min in a 5% brine solution.

Smoked fish products

Smoked fishes are known for their unique aroma, texture and golden yellow colour imparted by wood smoke. The method of smoking is popular, especially in the Northeastern states of India. This method combines salting, drying, and preservation by smoke components

produced during the thermal breakdown of wood by smouldering. Charring of the wood is not preferred while the smoking process. In the smoked products, the characteristic colour and flavour are imparted by the phenolic compounds present in the wood smoke. Heavily salted fishes were used to smoke for a longer period to get 'Hard cures'. Smoking of fish is usually done as an intermediate step in fish canning also.

There are two type of smoked products available, cold smoked and hot smoked products. Cold smoked products are usually made in traditional chimney kilns by smoking the fish for 36-72 hours at a temperature maximum of 40°C. The fish is smoked and dried at 75°C -80° C in case of hot smoking, unlike cold smoking this high temperature gives cooking partial sterilization effect on fish flesh. More conveniently, commercially available liquid smokes can be used to impart the aroma to fish products. Masmin of Lakshadweep is a very popular smoked fish product.

Marinated fish products

The value of fresh, frozen, salted, and dried fish can be increased by the process of marinating it with spices, sugar solutions, oil, plant extracts, acids, wine etc. to enhance the flavour, tenderness and juiciness. In addition, the process also helps to extend the shelf life of fish. These products are attracting customers because of their typical flavour and textural properties. Traditionally, acetic acid and salt were used for the marination process.

Marinades are semi-preserves, in which acetic acid inhibits microorganisms, giving characteristics of succulence and tenderness. The addition of acid will favour the action of proteolytic enzymes and the partial breakdown of protein into amino acids. The addition of salt aids in the extraction of salt out from the fish tissues and helps in the coagulation of protein. The addition of plant extracts, spices, sauce, cream, oil, mayonnaise, etc. can increase the flavour and shelf life of marinades further. There are three types of marinades. Cold marinades or 'marinade proper', as the name indicates the process does not involve any heat treatment of fish or ingredients used. The product is having a shelf life of several months at chill storage. Cooked marinades or 'jellied products' are generally packed in a jelly. Here acid-salt treated fish is further heat treated for better preservation. Low pH is maintained to avoid harmful bacteria, especially *Clostridium botulinum*. The shelf life of such products is 6 months. In the case of fried marinades, the pre-treated fish with acid and salt is baked or broiled in oil with or without breading. Then this can be immersed in acetic acid or sauce. Higher temperature inhibits the growth of most bacteria. The shelf life can be up to one year if properly stored at 0-8°C.

Fermented fish products

Fermented fish products are mainly popular in the north-eastern states of India. They are upgraded as speciality fish products because of their unique aroma usually described as umami. Fermented products have a meaty flavour and they are rich in nutrients. The process of fermentation is an age-old practice of fish preservation in which complex protein molecules in the fish are broken down into simpler molecules by the action of organic catalysts, enzymes,

or ferments which are stable at normal temperatures of storage. The method is suitable for both freshwater and marine fishes. Fermented products are of three distinct types, products in which fish retains its original form eg. cured fish, products in the form of a paste, and products in the form of liquid that is fish sauce. Seedhal, Ngari, Hentak, Lona ilish, etc. are examples of fermented fish products from India.

Fish pickle

Fish pickle is a widely accepted ethnic product commercially and a common product in households. Pickling is also a curing method in which edible products are preserved through anaerobic fermentation in brine or immersion in acid with spices. People relish this spicy adjunct with sour flavour as a food accompaniment to make the food palatable and appetizing. Vinegar is the preservative and flavouring agent used in fish pickles. Acetic acid aids in preservation by restricting the growth of spoiling microorganisms. Vinegar pickles are known as fresh pickles or quick pickles. The added salt in the pickle can actually add flavour to it, helps in extracting the excess water from fish, unlocking the flavourful juices, concentrating the juices, and ultimately gives a firm texture to the fish meat. The oil content in the pickle seals off the air from the pickle which helps to enhance the shelf life. The flavour can be improved by adding seasonings. The process of pickling enhances the shelf life to six months and more. Any fleshy fish can be used for preparing fish pickles like tuna and seer fish. It is important to maintain the pH of fish pickles below 4.5 to reduce microbial activity.

Mince based products

Mince is the edible fish meat that is separated from the inedible portions like the scale, skin, fins, and bones. It can be prepared by manual hand picking or by mechanical deboning technique. The fish mince serves as an intermediate stage for the preparation of a variety of value-added products. The fish mince devoid of inedible portions is consumer friendly in usage. Low value fishes with white meat are mainly preferred for the preparation to increase the utilization and demand of such resources by adding value to them. Fish mince-based products available in the market include fish sausage, fish sandwich spread, fish wafers/crackers, fish cookies, momos, papad, spring roll, samosa, fish flakes, fish spirals, etc.

Extruded products

There is a greater demand for snacks and ready to prepare products in the market. The process of extrusion is one of the popular methods of processing wherein soft mixed ingredients are forced through a perforated die designed to produce products of the required shape, size, and texture. In the process, small granular food or powdered particles are reinforced into large pieces. The process of Extrusion cooking or thermoplastic extrusion is considered as a High-Temperature, Short-Time (HTST) process, used mainly for developing cereal-based products rich in calories. The nutritional value of such products can be further increased by the addition of protein rich fish. During the process material fed into the extruder gets compacted, softens, gelatinized, and/or melts to form a plasticized material. The combined effect of high

temperature and mechanical shear causes the gelatinization of starch and denaturation of protein. The technology is used to develop pasta, crackers, baby food, snack foods, dried soups, dry beverage mixes, etc. The utilization of low-value fishes can be enhanced through this technology to develop products stable at ambient temperature like fish kure.

Battered and Breaded Products

Battered and breaded products are convenient products of greater demand in which the meat protein component is covered by a cereal-based coating. These products are also called as enrobed products or coated products as one food material is coated with another stuff. A coating is referred to as the batter and/or breading adhering to food after cooking. The external coating forms a stable crispy layer retaining most of the sensory and nutritional quality of the fish product. Coating by battering and breading enhances the appearance, colour, flavour, texture, and nutritional value of the product. It also acts as a moisture barrier by minimizing moisture loss during frozen storage and microwave reheating. It seals the flavour in the product by acting as a sealant that prevents natural juices from flowing out. Wet coatings are referred to as a batter. The batter is made from wheat flour or corn flour. Coating ingredients generally include polysaccharides, proteins, fats and hydrogenated oil, seasonings and water. A typical ratio of the batter mix to water is 1:2. There are three types of batter. Adhesion batters are mainly starch based that designed to adhere to the product whereas cohesion batters are mainly flour based which forms a shell around the product. Tempura batter is starch/flour based with a raising agent (sodium bicarbonate) for a puffy appearance, usually not followed by breading. A wide variety of bread crumbs are also available in the market like reclaimed and industrial bread crumbs. Deep fried coated products are ready to eat products, it can be par-fried/flash fried for storage (30second at 190°C) to cement the breading. The shelf life of stored products under frozen storage is 9-24 months.

Fish finger, cutlets, balls, nuggets, coated shrimp, coated squid rings, coated bivalve products, coated fish fillets etc. are the most commonly available form of battered and breaded products. Coated Nobashi is a high value specialty product made from shrimp, literally means stretched shrimp. Nobashi is peeled, deveined tail on shrimp stretched by mechanical means. The length can be increased by about 1-2 cm depending on the size of the shrimp by making parallel cuttings at the bottom and applying pressure using simple mechanical devices. During the coating process, the product will have more pick up due to increased surface area and attract customers because of the aesthetic appearance.

Surimi based products

Surimi is a Japanese term for water washed fish mince. The fish mince devoid of any pigments or blood stains has excellent keeping quality with the added cryoprotectants. It is defined as mechanically deboned fish mince from white fleshed fish that has been washed, refined, and mixed with cryoprotectants for better frozen shelf life. The washed mince will be white and have a unique texture that often provides a viscoelastic nature to the end product. Surimi-based products form an important dish in Japanese cuisine. Due to its high gel strength, it is

used as an intermediate product used for the preparation of a wide variety of value added products. Most commonly white fleshed fish with very less fat content is chosen for the product preparation.

Analogue products or "imitation products" or "fiberized products" and moulded products like fish ball form an important category under surimi-based products. These products are prepared to mimic the texture, flavor, and appearance of shrimp, crab or scallops even when they are prepared from the commonly available fish from the market. This involves the use of sophisticated technology for preparation and has not gained much popularity in the Indian market. Surimi-based products are popular in developed countries. Kamaboko is a traditional Japanese product prepared from surimi. It is a steamed cake made out of surimi. This product is known by different names according to the regions of production, ingredients used, cooking method, and shape of the product. Chikuwa is broiled kamaboko in the shape of bamboo. Steamed Kamaboko is called Sumaki or Mushiita. Fried kamaboko is called Tenpura or Satsuma Age. Hampen is boiled kamaboko in a square shape.

Thermally processed fish products

The growing popularity of safe packed seafood with enhanced shelf life has fueled the demand for canned fish globally. Canned fish products are ready to eat products. The process of canning or retorting is high temperature long term preservation method in which the food is preserved by the application of heat in a hermetically sealed container to obtain commercial sterility. The filling medium usually used in cans is oil or light brine. The double sealed robust cans maintain sterility throughout the storage period at ambient temperature. Canned tuna, herring, mackerel, and sardines are popular in the markets. Instead of metal cans, now canned products are more common in retort pouches. 3-ply laminated flexible pouches consisting of polyester/aluminium/cast polypropylene are widely in use. Canned sardine in oil, tuna chunks in oil and brine, tuna flakes in oil, fish curry, etc. are a few examples of products available in the markets. The expected shelf life of canned fish is minimum of one to two years.

Accelerated freeze dried products

Accelerated freeze drying is a novel technology of food preservation in which water from the frozen product is removed by the process of sublimation under vacuum. The method is expensive and finds easy acceptance in the case of high value food products. Properly processed freeze dried products are comparable with the fresh material in case of flavor, color, and nutritive value as there will not be product shrinkage, case hardening, thermal degradation of proteins, deteriorative changes in color or flavor and products will get rehydrated rapidly. Further, freeze dried products can be stored under ambient storage conditions without any additional cost for storage and it is convenient to use. The reported shelf life of freeze dried products is more than two years. Instant fish soup mixes, prawn cakes, pre-cooked ready to serve salads are some products prepared using this technique having consumer acceptance. In India, freeze drying is employed for processing shrimp, squid rings, etc.

Live Fish

There is a greater demand for live fish for food purposes and it usually fetches a high price as the freshness is ensured in the marketing. Consumers often demand smaller and medium-sized fish in live form. Grouper, snapper, seabreams, seabass, red tilapia, reef fishes, air-breathing fishes, shrimps, lobster, crabs, clams, oysters, and mussels are examples of candidate fishes for live fish transport. The live fish trade of high-value fish is a lucrative business nowadays as it gives huge profits to the business. But the high rate of mortality of fish during transport is a big challenge in the trade. The ways to improve the survivability of fish are to be standardized for a continuous supply of fresh live fish to the consumers.

Speciality products from secondary raw materials

The term "fish wastes" in general indicates the non-edible portion of fish which includes the head, skin, bone, scale, visceral mass, and trimmings. Besides, fish species having mere or no market value, under-sized fishes as well as spoiled or physically damaged fishes will also be added to this category. By considering the potential for recycling, the term "fish wastes" has been replaced now as "rest raw material" and "secondary raw material". These waste materials are having potential for recycling as they are good sources of high-quality protein, minerals, fat, etc. and thus they are important sources of different secondary products. The technology has a huge scope, as developed products can be used for human consumption, animal nutrition, and agricultural applications. Different secondary products such as fish meal, fish oil, squalene, collagen, gelatin, chitosan, hydroxyapatite, proteolytic enzymes, pigments, calcium, fish protein concentrate, etc. are of high value having wide acceptance market including the food industry.

Conclusion

The process of value addition has immense potential to uplift the livelihood of the stakeholders especially women by expanding the array of products available in the markets. There is an ever increasing demand for fish based products in the global markets. The modern market demands healthy, nutritious, and tasty convenient products to replace the high calorie food items from the diet. The flow of new entrepreneurs with novel value added seafood products all over the world makes the seafood processing and marketing sector more competitive every day. Value addition of the resources is needed for improving profitability, to empower the fish farmers and women stakeholders and to provide better quality, safe and branded products to the consumers.

Smoking of Fishes

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Introduction

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 fisheries 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.

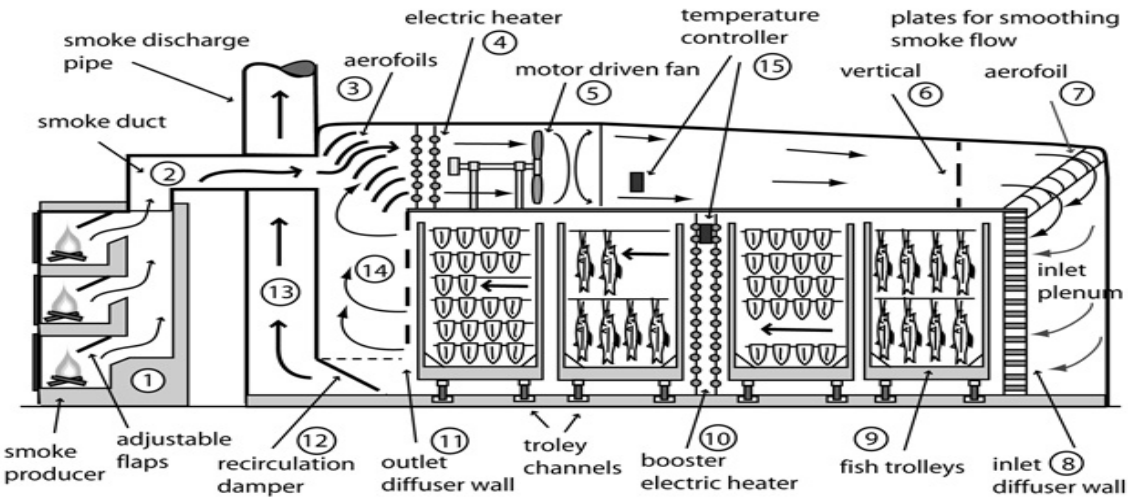

Fig. Illustration of the hot smoke airflow in the Torry smoking kiln

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.

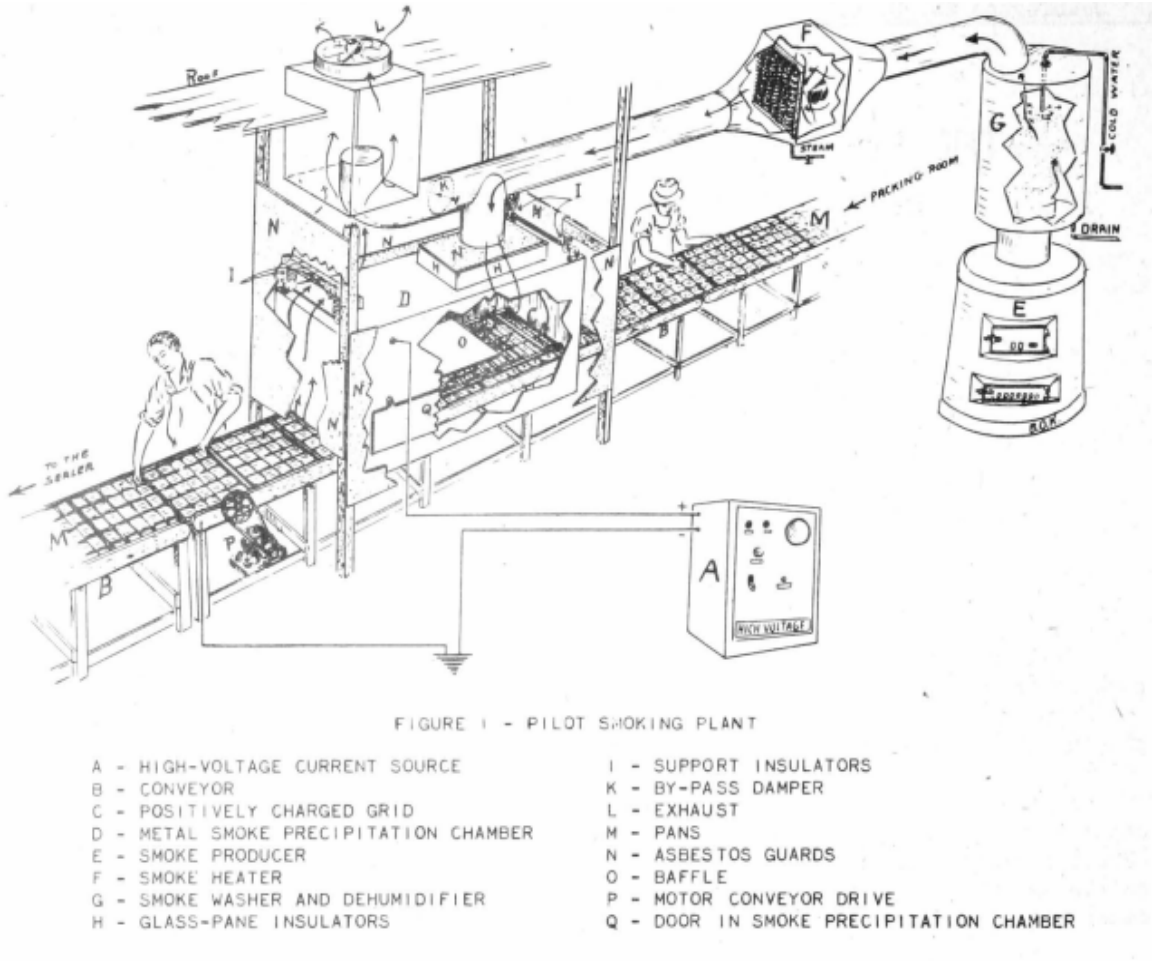

Fig. Schematic diagram of Electrostatic smoking with basic components.

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 (a_w) 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 fiber 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.

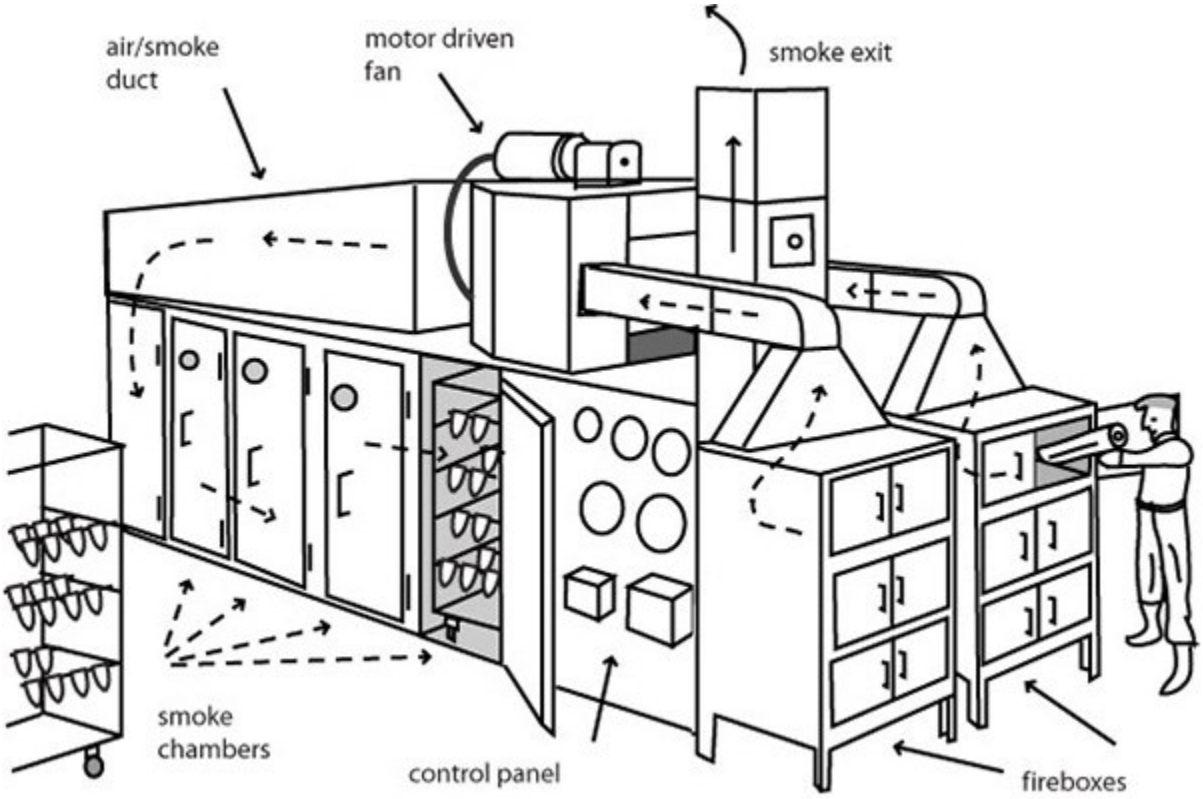

Fig. Smoking kiln

Potential hazards associated with smoking of fish

- **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 22-28º C. However, this temperature is not sufficient to eliminate the risk from *Listeria monocytogens,* a gram positive, facultative anaerobic, psychrotropic bacteria 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.

- **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.

- **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.

- **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.

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Vacuum and Modified Atmosphere Packaging of Fishes

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Introduction

Fish is regarded as highly perishable food commodity 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 sale-ability 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, and 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 the fish and shell fish products are appearance, texture and flavor. Appearance, specifically color, 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 is referred as skin packaging involves removal of air inside the pack completely and maintaining food material under vacuum conditions, so that the 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 odor 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 aspects 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 provide 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 analyzer 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.

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

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 microorganism, 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, gram negative psychrotropic bacteria. 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 favors 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 color. 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. Nitrogen is 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 is 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 color of the product is preserved
- The product retains its form and texture
- Reduces the growth of microorganisms
- 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 analyzer 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.*

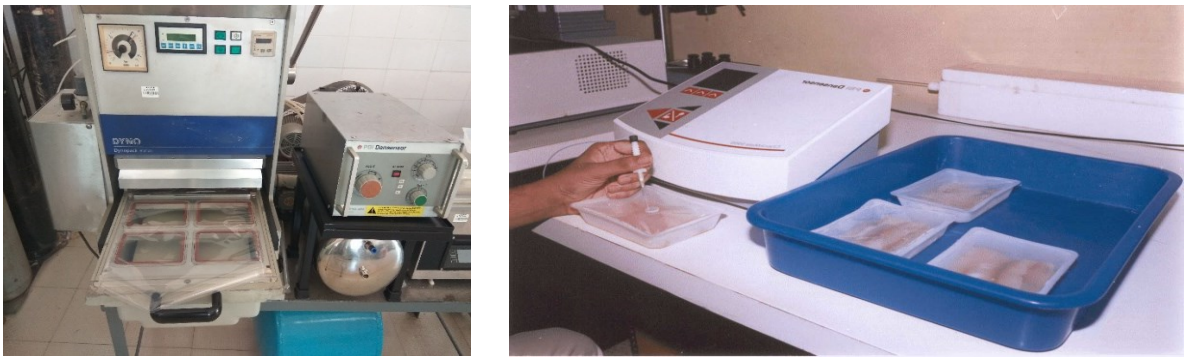

Fig 2. Modified Atmosphere packaging equipment and Gas composition analyzer

Apart from vacuum packaging and modified atmosphere packaging, smart packaging technologies, particularly active packaging can be used in place of these capital intensive technologies. For both vacuum packaging and MAP, capital investment is very high for purchase of machineries and food grade gases, in case of MAP. This is limiting its adoption in developing and under-developed countries. This can be overcome by adopting active packaging technologies, particularly oxygen scavenger in place of vacuum packaging and CO_2 emitter in place of MAP. These are not only cheap but they are also very effective.

Analytical Techniques in Profiling of Macro and Micronutrients in Seafood

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Introduction

Seafood is one of the highly traded food which provide essential food and hold a major share in the economy of many countries. It has been regarded as an excellent source of various nutritional compounds like proteins, healthy fats and rich source for a great number of nutritive and important components. The high amount of long-chain polyunsaturated fatty acids of the n-3 series such as Eicosapentanoic (EPA 20:5n-3) and Docosahexanoic acid (DHA 22:6n-3); the well-balanced content of essential amino acids; the high amount of taurine; the presence of antioxidants such as tocopherols; the exceptional concentrations of essential elements such as selenium and iodine; and the good digestibility of fish protein due to low amounts of connective tissue are some examples of the many benefits seafood offers, when consumed. These compounds are having preventive effects over many heart diseases and autoimmune disorders.

Proximate composition of Sea foods

The proximate composition comprises the percentage of the four basic constituents' viz. water, protein, fat and ash. The chemical composition of fish varies widely between species and among the individual fishes within the same species depending on age, sex, environment and season. Protein and ash content do not register much variation whereas lipid content shows remarkable variation and displays an inverse relationship with water content.

Moisture

It is estimated that over 35% of our total water intake comes from the moisture in the foods we consume. The difference in weight after heating the finely ground fish at a particular temperature for a defined duration gives the water content present in the sample. It is represented as g per 100g meat. Place a clean dry petri dish, kept in an oven at 105° C for 2 hours, cooled in a desiccator and weighed. About 10-20g portion of meat was taken in the pre-weighed petri dish, kept in an oven maintained at 105° C overnight. The petri dish was cooled in a desiccator and weighed again. The petri dish was again kept in an oven for half an hour, cooled as above and weighed again to get reproducible weights

$$\text{Moisture (\%)} = \frac{\text{Weight of moisture in thesample}}{\text{Weight of the wet sample}} * 100$$

Crude Protein

Fish provides about 14% of the world's need for animal proteins and 4%-5% of the total protein requirement. Both the amino acid composition and the digestibility of fish proteins are excellent. Fish is regarded as an excellent source of high-quality protein, particularly the

essential amino acids lysine and methionine. Protein analysis is highly important for the food industry, including the fish industry. Both the content and the properties of the proteins are important for the value and the quality of the products. Protein deficiency leads to various clinical and sub-clinical syndromes, such as impaired health, lowered resistance to infection and susceptibility to diseases.

The total content of proteins is usually determined by the Kjeldahl method. It is also possible to determine the nitrogen content using elemental analysis. The method includes sample digestion, neutralization, distillation, and trapping of ammonia and titration steps. The nitrogenous compounds in the sample are converted in ammonium sulfate by boiling with concentrated sulfuric acid. Upon distillation with excess alkali, the ammonia is liberated which is estimated by titration with standardized sulfuric acid. The advantage of this method is that it gives accurate results for all types of samples. Crude protein content was determination involves the following steps.

1. **Digestion**: 0.1-0.2g of wet sample was weighed in to a Kjeldahl flask. A pinch of digestion mixture (copper sulphate and potassium sulphate were mixed in the ratio 1:8 and finely powdered) and 10 ml of concentrated sulfuric acid was added. It was then digested over a sand bath by heating slowly till the solution starts boiling and then vigorously until the solution becomes colorless. The sample was then cooled and made up to the desired volume (100ml) according to the protein content of the sample. A blank was kept with distilled water.
2. **Distillation:** A conical flask containing 10 ml of boric acid with few drops of Tashiro's indicator (pink in color) was placed at the receiving end of the distillation apparatus in such a way that the tip of the condenser is slightly immersed in boric acid.5ml or any convenient volume of the made up sample was pipette out in to the distillation apparatus.10ml or known volume of 40% NaOH as shown excess by phenolphthalein indicator was added in to the distillation unit followed by rinsing with little distilled water. The unit was made air tight. The content was steam distilled till the boric acid solution in the flask doubles or for 5minutes. The color of the solution turns green. The flask was lowered and the condenser tip was washed with little water.
3. **Titration:** The solution in the receiving flask is green at this stage. The content was titrated against N/100 sulfuric acid until the original pink colour is restored. The volume of acid used for titration was noted. The distillation and titration process was repeated to get concordant value.

i. 1ml 0.01N/100 Sulfuric acid = 0.14mg Nitrogen

ii. $\text{Protein Content} = \frac{X*0.14*V*6.25*100}{V1*W*1000}$

1. X=Titre value of the sample
2. V=Total volume of digest
3. V1=Volume of digest taken for distillation
4. W=Weight of sample taken

Crude Fat

Fat soluble in organic solvents can be extracted from moisture free samples. The solvents commonly used includes petroleum ether, ethyl ether etc., the solvent is evaporated and fat is estimated gravimetrically. 5-10g of dried sample was weighed accurately in to a thimble and cotton plugged. The thimble was then placed in a Soxhlet apparatus and 1and half volume of ether was added and distilled for 16 hrs.

Figure 1: Soxhlet Apparatus

The apparatus was cooled and the solvent was filtered in to a pre-weighed conical flask. The flask of the apparatus was rinsed with small quantities of ether and the washings were added to the above flask. The ether was removed by evaporation and the flask with fat was dried at 80-100 °C, cooled in a desiccator and weighed

$$\text{Fat content}\left(\frac{\text{g}}{100\text{g}}\right) = \frac{\text{Weight of fat}}{\text{Weight of sample}} * 100$$

Ash

Ash is the residue obtained after incineration of the dry material at high temperature and appears as grey-white coloured powder. Silica crucible was heated to 600 °C in a muffle furnace for one hour, cooled in a desiccator and weighed. 2g of dried sample was weighed accurately in to a crucible and heated at low flame by keeping on a clay triangle to char the organic matter. The charred material was then placed inside the previously set (600 °C) muffle furnace and heated for 6-8 hrs which gave a white or grayish white ash. The crucible was cooled in a desiccator and weighed. The crucible was heated again for further 30mins to confirm completion of ashing, cooled and weighed again.

$$\text{Ash content}\left(\frac{\text{g}}{100\text{g}}\right) = \frac{\text{Weight of ash}}{\text{weight of sample}} * 100$$

Figure 2: Muffle Furnace

Lipids in Sea foods

Lipids are heterogeneous group of compounds and can be defined as the fraction of any biological material extractable by solvents of low polarity. Any material extracted with 'fat solvents' like ethyl alcohol, ether, chloroform, hexane, petroleum ether etc. is classified as a lipid. The important type of compounds included in this group are fatty acids, glycerides, phosphoglycerides, sphingolipids, aliphatic alcohols and waxes, steroids and combination of the above type of compounds with proteins, peptides carbohydrates etc. In the case of fish tissues, the major components of lipids are triacylglycerol and phosphoglycerides, both containing long chain fatty acids.

Phospholipids, another important constituent of lipids are essential components of cell membranes. It is the lipid-globular protein mosaic structure that determines important functions like permeability of cell membranes, transport of various substances into and outside the cell. Various types of phospholipids are essential for the proper functioning of the cell. Unlike in the case of depot fat, the proportions of phospholipids do not show wide variation. Normally it is in the range of 0.5 to 1% of tissue.

In fish muscle, lipids are the third major constituent in quantity. Fat varies between species and also within the species between different organs. Fish with fat content as low as 0.5% and as high as 18-20% are common and the major fish lipids are triacylglycerol and phosphoglycerides containing long chain fatty acids. Squalene and wax esters are the other components seen in high concentration in certain fish meat.

Determination of total lipids are generally based on solvent extraction followed by gravimetric determination.The wet 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 and disturbing the equilibrium between chloroform and methanol

separates the chloroform soluble fat. Depending on the fat content, extract about 25-50 g meat with about 15 volumes of chloroform-methanol mixture. Filter the extract using a Buckner funnel with Whatman No.1 filter paper applying little vacuum and the extraction, filtration is carried out thrice. Take the combined extract in to a separating funnel. Add 20% of the volume water, mix well and allow to separate overnight. Concentrate lipid to a known volume, say 10 ml, by evaporating the solvent in a vacuum flash evaporator and keep under nitrogen. Take one ml of aliquot in a pre-weighed test tube and allow it to dry. Cool the test tube in a desiccator and weigh.

$$Fat\ content\ \left(\frac{g}{100g}\right) = \frac{W2 * V1 * 100}{V2 * W2}$$

Where V1 =Total volume of extract
V2=Volume of extract taken for drying
W2=Weight of dried lipid
W1=Weight of sample for fat extraction

Analysis of Fatty acid

The analysis of fatty acids in a fish tissue involves mainly three steps: lipid extraction, preparation of fatty acid derivatives, and gas chromatographic (GC) analysis. For decades, GC has been the most applied method for fatty acids analysis. The success of GC with flame ionization detector (FID) for the analysis of fatty acids is based on the ability of this technique to separate dozens of fatty acids depending on the type and the length of the column, and on the economical accessibility of the GC instrumentation that is actually present in most analytical laboratories.

Saponification of fats liberates fatty acids from triglycerides. The fatty acids are derivatised into their corresponding fatty acid methyl esters by reflexing with BF_3 methanol reagent and the fatty acid profile analysed using Gas Liquid Chromatography.

a. Extraction of fatty acids

Weigh 2g oil into a round bottom flask and add 10 ml alcoholic KOH. Reflux for 20 min and cool to room temperature. Extract non-saponifiable matter with 10 ml portions of hexane or petroleum spirit. Acidify the aqueous fraction and re-extract with petroleum either to separate fatty acids. Wash the fatty acid portion repeatedly with water. Pass the fatty acid portion through anhydrous Sodium sulphate and evaporate to dryness.

b. Preparation of methyl esters

Add 5 ml of BF_3- CH_3OH reagent to the extracted free fatty acids. Reflux for another 2 min. Add to the mixture sufficient saturated sodium chloride (10 ml) to separate the fatty acid methyl esters. Extract the contents of the flask into ether layer. Dry ethyl layer over anhydrous sodium sulfate and evaporate the petroleum ether fraction to 2 ml.

Inject into Gas Chromatogram for analysis and the operating conditions are set for separation of fatty acid methyl esters using Gas Chromatography -FID method. The Gas Chromatograph is set at required temperature with optimum flow of carrier gas. Programme of GC Injector 260°C; FID-275°C; Capillary column, PE Elite 225 (30 m, 0.25 mm 1.d, .25 um) Carrier gas- Nitrogen at 0.6m/min; Air 30ml/min and Hydrogen 30ml/min for FID Temperature programme-110°. After initial hold of 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 12ml. Samples are identified by retention time by comparing with respective standards using software. Area of each component is obtained from the computer-generated data and concentration calculated using the software by external standard method.

Figure 3: Perkin Elmer Clarus 580- Gas chromatograph -FID

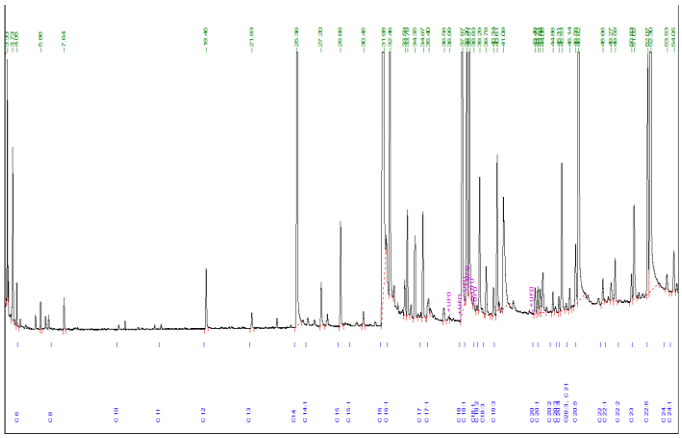

Figure 4: Chromatogram of Fish

The fatty acid composition of fish, shellfish, seafood products, and encapsulated fish oils products have been extensively studied. Clinical and epidemiological studies indicated that the consumption of fish and fish oils renewed interest in investigating the lipid content and the fatty acid composition of fish and seafood products.Marine-based fish and fish oil are the

most popular and well-known sources of n-3 polyunsaturated fatty acids (PUFAs), namely, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These n-3 PUFAs are known to have variety of health benefits against cardiovascular diseases (CVDs) including well-established hypotriglyceridemic and anti-inflammatory effects as well as antihypertensive, anticancer, antioxidant, antidepression, antiaging, and antiarthritis effects.

Amino acid Profiling

Proteins and amino acids are important biomolecules which regulate key metabolic pathways and serve as precursors for synthesis of biologically important substances and amino acids are building blocks of proteins. Fish is an important dietary source of quality animal proteins and amino acids and play important role in human nutrition. Seafood contains all nine essential amino acids. It is an excellent choice for meeting our daily protein needs and the protein in seafood is highly digestible. This advantage makes seafood an excellent food choice for people of all ages.

Dietary protein must be balanced in composition with all essential amino acid in proper proportion. Hence analysis of dietary proteins for amino acids become essential. Most modern technique for amino acid analysis is High performance liquid chromatography (HPLC). Inadequate uptake of quality proteins and calories in diet leads to protein energy malnutrition (PEM) (or protein-calorie malnutrition, PCM) which is the most lethal form of malnutrition/hunger. Kwashiorkor and marasmus, the extreme conditions of PCM mostly observed in children, are caused by chronic deficiency of protein and energy, respectively. PCM also occurs in adults who are under chronic nutritional deficiency

Total Amino acid

Protein is hydrolysed to 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) with a pH gradient is used to elute the amino acid 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 hypochlorite solution, using a fluorescence detector.

Weigh about 100 mg of finely homogenized fish mince in to a test tube and add 10 ml of 6N HCI in to the test tube. Seal the tube after filling nitrogen and digest the contents of the tube by keeping at 120°C for 24 hours in an oven. Cool the test tube and filter the contents using Whatman No 1 filter paper. Rinse the tube with distilled water and filter. Evaporate filtrate in a vacuum flash evaporator. Add deionized water in to the tube and continue evaporation until the contents are acid free. Dissolve the free amino acids in buffer A and inject in to HPLC. The amino acids are separated in a HPLC equipped with an ion exchange column. Two buffers (pH 3.2 and pH 10) with a pH gradient is used to elute the amino acid from the column. 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 hypochlorite

solution, using a fluorescence detector. The separation and quantification of amino acids are carried out with HPLC with an ion exchange column. Filter the samples using 0.45µm syringe filter and inject appropriate quantities in to the HPLC system as per the specifications of the injector.

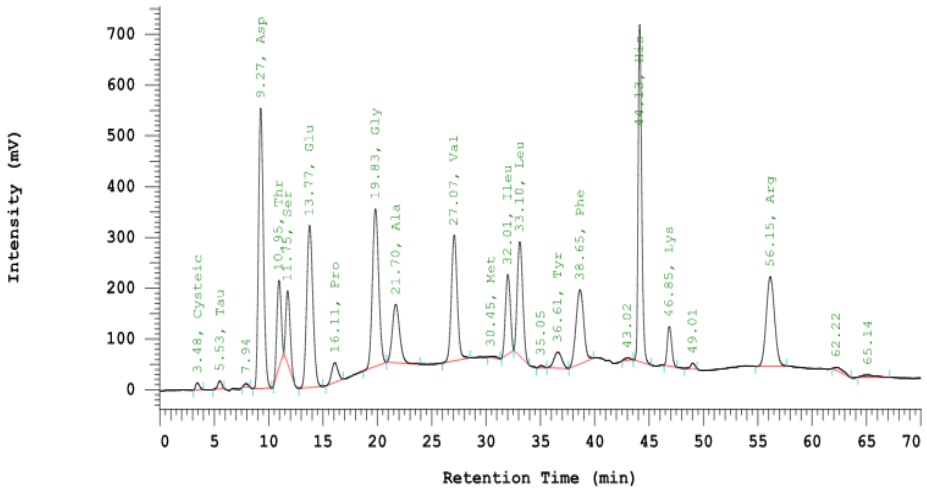

Figure 5: Chromatogram of amino acids

Figure 6: Hitachi Amino acid Analyser

Estimation of Tryptophan

Tryptophan being labile to the conditions of hydrolysis is estimated spectrophotometrically after alkali hydrolysis of the protein. Under acidic conditions of reaction, the 5-hydroxy furfural resulting from sucrose forms pale green colored condensation product with thioglycolic acid, which reacts with tryptophan in the hydrolyzed protein giving a pink coloured complex which is measured is measured at 500 nm

Weigh about 200 mg of finely homogenized fish mince in to a test tube. Add 10 ml of 5% NaOH in to the test tube. Seal the tubes after filling nitrogen and digest the contents of the tube by keeping at 120°C for 24 hours in an oven. Neutralize the contents after hydrolysis to pH 7.0 using 6N HCI. Total volume is made to 100 ml and filter through Whatman No.1 filter paper. 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 and cool. Add the aliquots (0.1-0.8ml) sample to the test tube and mix. Make the volume of the test tube to 5 ml with 0.1N HCI and leave aside for five 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.

Vitamins

Fish is a rich source of vitamins, particularly vitamins A, D and E from fatty species, as well as thiamine, riboflavin and niacin (Vitamins B1, B2 and B3). Vitamin A from fish is more readily available to the body than from plant foods. Among all the fish species, fatty fish contains more vitamin A than lean species. Vitamin A is also required for normal vision and for bone growth. As sun drying destroys most of the available vitamin A, better processing methods are required to preserve this vitamin. Vitamin D present in fish liver and oils is crucial for bone growth since it is essential for the absorption and metabolism of calcium. It also plays a role in immune function and may offer protection against cancer. Oily fish is the best food source of unfortified vitamin D. Vitamin D is not found in many foods and tends to be a vitamin that many vulnerable groups go short of, such as teenage girls and the elderly people. Fish is also a good source of the B vitamins and can provide a useful contribution to the diet. The B group of vitamins is responsible for converting food to energy in the cells of the body and they help with the function of nerve tissue.

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 clean-up and concentration of vitamins.

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, and 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. The column used is 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 fat soluble Vitamins elute from the column in the order Vitamin A, Vitamin D, Vitamin E and Vitamin K. The wavelength used for eluting different Vitamins is as follows. 265nm for vitamin D_1, 325nm for Vitamin A, 291nm for Vitamin E and 250nm for Vitamin K. The Vitamin content in the unknown sample is determined from the linear graph drawn for the standard.

Figure 7: Shimadzu HPLC PDA

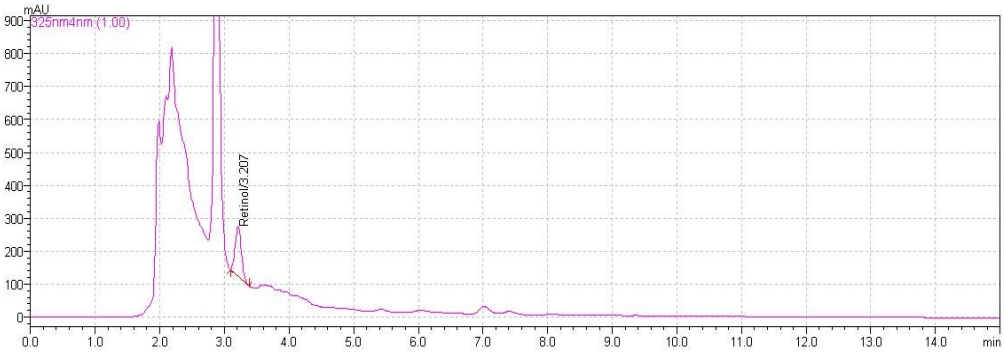

Figure 8: Chromatogram Vitamin A

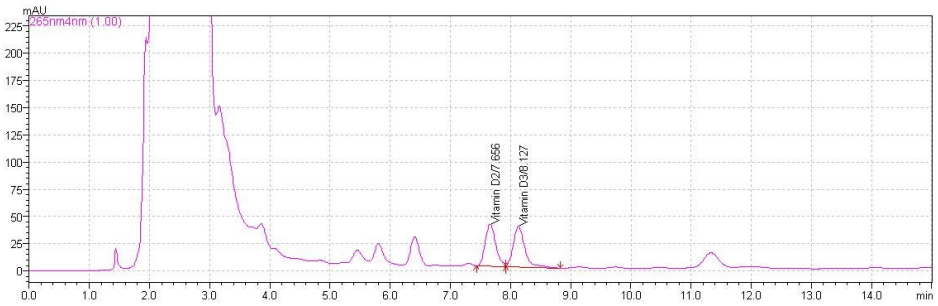

Figure 9: Chromatogram Vitamin D

Minerals

Minerals are inorganic elements necessary in the diet for normal body functions. They can be divided into two groups: macro-minerals and micro-minerals based on the quantity required in the diet and the amount present in fish. The common macro-minerals are calcium, phosphorus, magnesium, sodium, potassium, chloride, and sulfur. These minerals regulate osmotic balance and aid in bone formation and integrity Micro minerals or trace minerals are required in small amounts as components in enzyme and hormone systems. Common trace minerals are copper, chromium, iodine, zinc and selenium.

Fish is a good source of almost all the minerals present in seawater. Calcium and phosphorus account for more than 75% of the minerals in the skeleton. Besides forming a part of skeleton, phosphorous has many metabolic and physiological roles in fish. Elements of special nutritional significance such as iodine and fluorides are also present in fish. Sulphur is present in the form of amino acids as fish is a good source of sulphur containing amino acids, cysteine and methionine. Copper and iron are associated with muscle tissues. Cobalt is present in the form of Cyanocobalamin (Vitamin B_{12}). It should be noted that the sodium content of fish meat is relatively low which makes it suitable for low-sodium diets. Fish can absorb many minerals directly from the water through their gills and skin, allowing them to compensate to some extent for mineral deficiencies in their diet. Fish contains most of the 90 naturally occurring elements. The average ash content in the edible part of the fish may range from 0.5-1.8% and it is an indication of total minerals.

Under mineral profiling the determination of alkali metals, viz; Na, K, and Ca are normally determined by flame photometer method. The metals in any other biological samples can be analysed by atomic absorption spectrophotometry. The technique makes use of absorption of light by the particles or atom to assess the concentration of an analyte in a sample and depends on the Beer-Lambert law. The electrons of the atoms in the atomizer are promoted to higher orbitals for a short period of time by absorbing a set quantity of energy from a light of a given wavelength depending on the metal used which gives the technique its elemental selectivity. The signal generated in the flame is proportional to the concentration of the element being

measured.The ash estimated after proximate analysis is dissolved in 100 ml 6N HCl quantitatively. The solution is appropriately diluted and aspirated in to the Photometer for quantification.

Figure 10: Atomic absorption spectrophotometry

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Seaweeds: Scopes and potential

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Introduction

The consumption of marine foods is increasingly gaining attention due to awareness among people in regard to diet and health (Granato et al., 2020). Currently, several marine based foodstuffs have been developed and marketed, offering enhanced health benefits (Annunziata & Vecchio, 2011). Seaweeds are relatively unexplored and promising sources of novel molecules like peptides and carbohydrates possesing nutraceutical properties (Lafarga et al, 2020). Further seaweeds are a potent source for the phycocolloid industry (agar, carrageenan, fucoidan and algin). The fame of seaweed in the international trade is peculiarly for phycocolloids and products of laminarin and fucoidans.

Seaweeds are primitive plants, macrophytic algae which lacks true roots, stems and leaves belonging to genera Chlorophyta, Phaeophyta and Rhodophyta (Fouda et al., 2019) representing a diverse group of approximately 10,000 species (Makkar et al, 2016). They are cultured in abundance in the coastal areas of Tamil Nadu, Gujarat, Lakshadweep, Andaman and Nicobar Islands. Only few of these species are utilized for food applications, mainly as food additives or flavouring materials, particularly in Asian countries and is served in meals of Japanese approximately to 21% (Yoshinaga et al., 2001). Seaweeds are apt for human as well as animal feeds and are taken in various forms like raw salad, soups, meals and condiments in China, Japan, USA, France and Chile, etc (McHugh, 2003). Edible seaweeds are considered to be a good source of antioxidants, dietary fibers, essential amino acids, vitamins, phytochemicals, PUFAs, and minerals. The marine macro- and micro- algae are considered one of the excellent natural antioxidants and antimicrobial (Cox et al., 2010; Chen et al., 2009), vitamins (A, B1, B2, B3, B5, B7, B9, B12, C, D and E) and minerals (Ca, P, Na, K and I) sources along with polysaccharides holding dietary fibres with prebiotics and biological activities of potential medicinal value (Dhargalkar and Pereira, 2005; Smit, 2004). It is believed that seaweed bioactive components significantly increase the health status if they are consumed throughout life (Biesalski et al., 2009). Apart from therapeutic properties, seaweeds are gaining importance because of their ability to act as texture modifier i.e. stabilizer, texture enhancer, viscosity modulator, gelling agents, etc. in various food products.. Due to consumer demand towards natural and safe substrate, emphasis on several plant based products is on the eye for "green" additives. The polyphenolic compounds from seaweed have well documented antioxidative and antimicrobial properties which helps in prevention of spoilage due to oxidation and food borne pathogens (Gupta & Abu-Ghannam, 2011).

The incorporation of seaweed bioactives in fortified food provides an opportune approach (Kadam and Prabhasankar, 2010). Seaweed based functional food products like alginate and carrageenan powder, fucoidan fortified phyto-complexes, alignin, minerals, vitamins, ß-

carotene along with seaweed protein powder, etc. covers a confined niche in the market. Seafood constituents, seaweeds i.e. macro and microalgae can be added in various food stuffs prepared from meat, dairy, fish, vegetables, fruits, etc. to make them more functional, thus improving their health promoting characteristics. (Jimenez-Colmenero, 2007; Mikami & Hosokawa, 2013). For instance, bioactive peptides from seaweeds like algal fucans, galactans and alginates exhibits anticoagulant, anticancer, and hypercholesterolemic activities (Lordan, Ross, & Stanton, 2011). The beneficial properties of seaweeds are ascribed to the complex phytochemicals compounds comprising phenolic compounds, sulphated polysaccharides and organic acids which exhibits antioxidant, antimicrobial, anticancer and antiviral activity (Apostolidis et al., 2008; Liu, 2003). Antioxidants prevent oxidation by transforming free or peroxy radicals into non-radicals by donating electrons and hydrogen, chelating transition metals and dissolving thereby generating peroxidation compounds (Enrique & Lester, 2002). The use of antioxidants is an effective way to minimize or prevent lipid oxidation in foods, retarding the formation of toxic oxidation products, maintaining nutritional quality with prolonged shelf life. Synthetic antioxidants (BHA, BHT, THBQ) and antimicrobials (sodium benzoate, sodium nitrite and sorbic acid) are used extensively for safety and quality control in food industry. However, the toxicity regarding use of synthetic antioxidants and antimicrobials is well documented which force the food processing sector to switch towards use of natural preservatives (Andarwulan et al., 2010; Ayaz et al., 2008).

Biochemical composition of seaweed

The detailed chemical composition of seaweeds is not well known like terrestrial plants (Kadam and Prabhasankar, 2010), but these are considered one of the excellent source of natural antioxidants and antimicrobials (Cox et al., 2010; Chen et al., 2009), vitamins (A, B1, B2, B3, B5, B7, B9, B12, C, D and E) and minerals (Ca, P, Na, K and I) along with polysaccharides holding dietary fibres with prebiotics and bioactives of potential medicinal value (Dhargalkar and Pereira, 2005; Smit, 2004).

Seaweeds are rich source of protein with all essential amino acids. The proteins content varies from 10-40% (w/w) dry weight based on the season and species (Murata and Nakazoe, 2001) with the highest in red seaweed. Certain green seaweed species like Ulva, Caulerpa contains high level of arginine and glycine (Fouda et al., 2019). The free amino acid section of seaweed is predominated by taurine, alanine, amino butyric acid, ornithine, citrulline, and hydroxyproline (Holdt and Kraan, 2011). Among all the groups of marine algae, highest concentration of taurine is reported in red algae. Among the proteins present in seaweeds, lectins, a hemagglutinin protein binds with carbohydrates and actively takes part in host-pathogen and cell to cell interactions, identifying and binding carbohydrates to exert functional effects (Mori et al., 2005). Seaweed peptides (inactive in the amino-acid sequence of the parental protein) obtained through the enzymatic digestion process have displayed biological and mineral binding activities (Smit, 2004).

Studies conducted reveals that seaweeds have slightly elevated levels of total fibre (not readily digested in gut) compared to terrestrial foodstuffs comprising mainly alginates, carrageenan

and agar (Brownlee et al., 2005) depending on the type of seaweed. Serving of 8 g seaweed provides around 12.5% of daily fibre needs i.e. 24 g/day. Marine algae have 10-100 times higher mineral content than vegetables (Nisizawa 2002) and can be labelled as supreme natural source of minerals (chiefly due to their habitat and the diverse minerals absorption from marine environment), but their large amount consumption can be detrimental. Accumulation of calcium is higher, moreover, sodium and potassium (Na:K ratio is below 1:5), iron, copper levels are also relatively higher than terrestrial foodstuffs like meats, spinach, etc. and can be considered as good minerals supplement. Ash content in seaweeds is reported upto 55% on dry weight basis (Rupérez 2002). The main source of lipids in seaweeds are glycolipids followed by phospholipids (Bhaskar et al. 2004, Khotimchenko, 2005) and content is relatively lower as compared to marine organism, constituting 4.5% on a dry weight basis which varies with the season and environmental factors. They are rich in fatty acids with essential fatty acids as well as omega fatty acids, moreover, among all the seaweeds red algae and green algae contains approximately 33 and 29 fatty acids respectively (Fouda et al., 2019). With the decrease in environmental temperature accumulation of polyunsaturated fatty acids (PUFAs) is common and the cold waters aquatic species generally contain larger quantities of PUFAs (Narayan et al. 2006). For instance, the amount of phospholipids in various red seaweed species varies from 10% to 21% of the total lipid (0.5–2.6 mg/g on dry weight basis). Besides, the phenolic content varies from <1% to 14% (dry seaweed biomass) with the highest content in Ascophyllum and Fucus i.e. 14 and 12% respectively (Mabeau and Fleurence 1993).

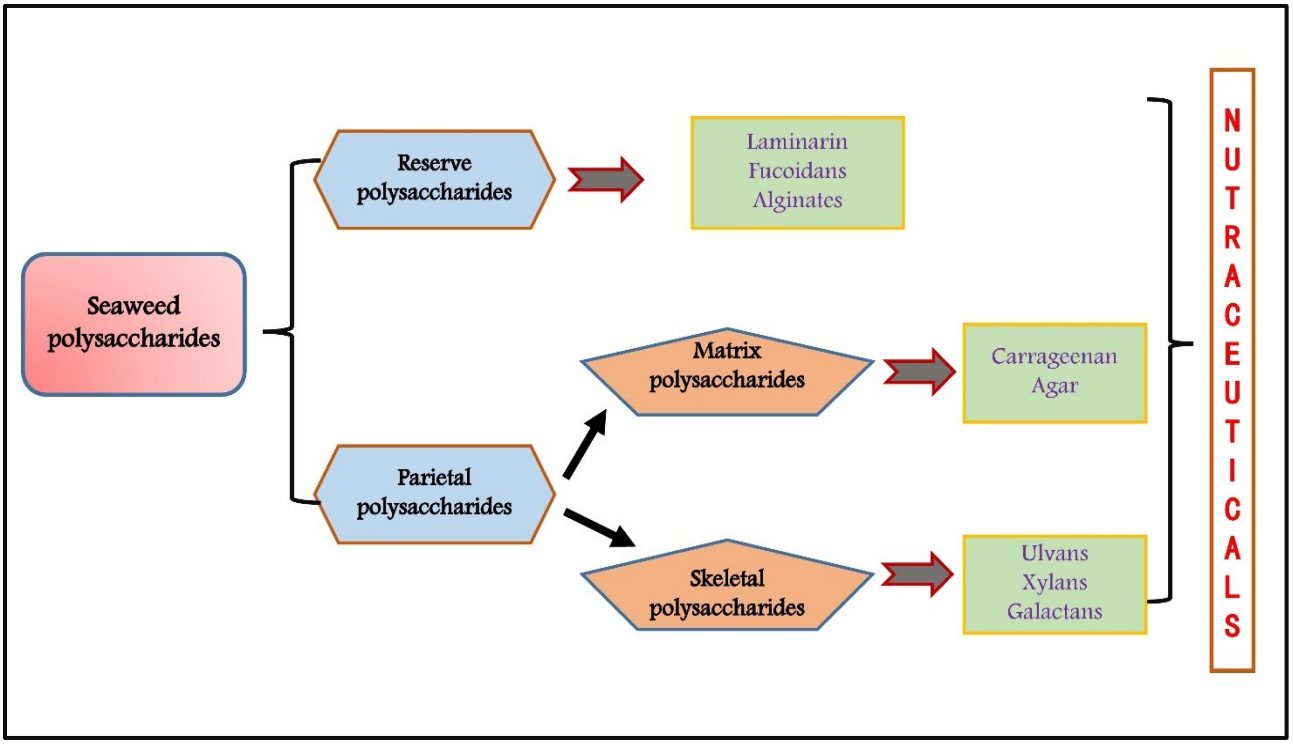

Fig 1. Seaweed derived nutraceuticals

Table 1. Bioactive compounds and Polysaccharides from various seaweed species

S.No	Bioactive compounds	Seaweed species	Reference
1	Total polysaccharides	Saccharina latissima, Sargassun pallidum	Rengasamy et al. 2014b Murata and Nakazoe 2001; Ye et al. 2008 Athukorala et al. 2007 Kumar et al. 2008, Hold et al. 2011
2	Carrageenan	Chondrus crispus, Eucheum cottonii	Fernandez et al. 1989 FAO, 2008; Hayashi et al 2008; Carlucci et al. 1997 Caceres et al. 2000 Rodrigueza and Montaño 2007
3	Agar	Gracilaria cornea, Gracilari domingensis	FAO, 2008; Fernandez e al. 1989
4	Algins/alginic acid	Laminaria digitata, Laminari hyperborea	Jensen and Haug, 1954 Morrissey et al. 2001; Kin and Lee, 2008; MacArtai et al. 2007; Jensen an Haug, 1956
5	Mannitol	Saccharina latissima, Laminari hyperborean, Sargassun mangarevense, Ascophyllun nodosum:	Zubia et al. 2008 MacArtain et al. 2007
6	Phycarine	Laminaria digitata	Mayer et al. 2007
7	Porphyran	Porphyra umbilicalis	MacArtain et al. 2007 Plaza et al. 2008, Noda 1993
8	Fucoidan	Fucus vesiculosus, Ascophyllun nodosum	Berteau and Mulloy 2003 Li et al. 2008a; Zhao et al 2008
9	Laminarin	Fucus vesiculosus, Laminari hyperborea	Deville et al. 2004 Shanmugam and Mody

			2000; Miao et al. 1999
10	Ulvan	Ulva lactuca, Ulva rigida	Lahaye 1998; Angell et al 2014, Mata et al. 2016 Onda et al. 2017
11	Floridoside	Porphyra umbilicalis, Palmaria palmata	MacArtain et al. 2007
12	Xylans	Caulerpa lentillifera, C. racemosa Bryopsis maxima, C. anceps Halimeda cuneata	Lahaye et al. 2003 Kiyohara et al. 2006
13	Total protein	Undaria spp., Sargassum spp.	Bird et al. 1993
14	Lectins	Ulva sp., Eucheuma amakusaensis	Kawakubo et al. 1997 1999, Sugahara et al 2001; Liao et al. 2003 Mori et al. 2005 Matsubara et al. 1996;
15	Phycobilliproteins	Palmaria palmata, Gracilaria tikvahiae	Chronakis et al. 2000 Wang et al. 2002
16	Phlorotannins	Cystoseira trinodis, Fucus serratus, Ascophyllum nodosum Halidrys siliquosa	Sathya et al. 2017; Gage et al. 2020.
17	Carotenoids	Palmaria, Sargassum horneri Cystoseira hakodatensis, and Undaria pinnatifida	Yuan 2008, Terasaki et al 2012
18	Halogenated compounds	Laurencia spp., Plocamium and Chondrococcus spps. Asparagopsis and Bonnemaisonia	Dembitsky and Srebnik 2002, Blunt et al. 2003 Knott et al. 2005
19	Sterols	C. crispus, Laminaria, Undaria Palmaria and Porphyra	Sanchez-Machado et al 2004, Whittaker et al 2000
20	Phenolic Acids	Dasycladus vermicularis Ascophyllum nodosum, Bifurcaria bifurcata, and Fucus vesiculosus	Agregán et al. 2017 Farvin et al. 2013

21	Bromophenols	Rhodomela confervoides Polysiphonia morrowii and Ulva lactuca	Fan et al. 2003, Ko et al 2019, Flodin et al. 1999 Shi et al. 2010
22	Flavonoids	Porphyra yezoensis, Padina arborescens and Acetabularia ryukyuensis	Yoshie et al. 2000, Ismai et al. 2016
23	Mycosporine-Like Aminoacids (MAA	Rhodophyta spp., Rhodomonas baltica, Porphyra and Rhodomonas marina	Llewellyn et al. 2010 Stengel et al. 2011

Antioxidant potential of seaweed

Seaweed are considered to be a rich source of antioxidants. Over last few years, the natural sources of antioxidant extracts from seaweeds have been well-developed in various countries. For instance, carnosine and glutathione are reported in certain seaweed species though these antioxidant peptides are usually present in animal muscle (Harnedy and FitzGerald, 2011). Lipid oxidation, free radical chain mechanism is the main reason for the development of ROS and off-flavors. The chain mechanism involves three steps (initiation, propagation and termination) initiation leads to the formation of free radicals i.e. peroxyl radicals, propagation wherein radicals react with MUFA/PUFA to form lipid hydro peroxides and finally termination where the two peroxyl radical react to produce a non-radical species. Antioxidants inhibits the initiation or propagation reactions by deactivating or scavenging free radicals, thereby detaining the lipid oxidation. The potential antioxidants reported in seaweeds are fucoxanthin, astaxanthin, phlorotannins (polyphenols), phospholipids, flavonoids, bromophenols, polysaccharides, etc. The phenol rings in polyphenolic compounds act as electron traps and accounts towards multifunctional properties like hydroxyl radicals, peroxy radicals or superoxides scavenger, powerful metal chelator (Santoso et al., 2004). Phlorotannins present in seaweeds are reported to be more potent than plant polyphenols (Wang et al., 2009). Several studies have reported a high correlation between total phenolic content and antioxidant activity (Chew et al., 2008; Wang et al., 2009).

Chew et al., 2008 reported the antioxidant activities of three different seaweed varieties (Padina antillarum, Caulerpa racemosa and Kappaphycus alvarezzi) in-vitro by various assays i.e. DPPH (2,2-diphenyl-1-picrylhydrazyl), FRAP (ferric reducing antioxidant power), FIC (ferrous ion chelating) and BCB (β-carotene bleaching) and found high antioxidant activity with BCB assay for all the three seaweed varieties and recommended to use them as preservatives efficiently and a number of seaweed species have the potential to be used in pharmaceutical industries (O'Sullivan et al., 2011). Souza et al. (2012) conducted a study to isolate polysaccharides from Gracilaria birdiae with aqueous extraction at 90 °C and antioxidant activity evaluation through DPPH assay. It was found that the extract possess remarkable antioxidant activity and this is attributed due to the presence of sulphate groups (Qi et al., 2005; Wang et al., 2009). Kuda et al., 2005 documented strong antioxidant activity

in linoleic acid peroxidation assay (22 mg catechin equivalents/g dry sample) using water extract of Scytosiphon lomentaria.

Incorporation as antioxidant in food

Presence of high bioactive peptides assisting high antioxidant activity in seaweeds is reported frequently now adays (Admassu et al., 2018, Wada et al., 2015). Addition of seaweeds in various meat and meat based products is well documented. Cofrades et al. (2008) and López et al. (2009) reported the use of Enteromorpha, Himanthalia elongata, U. pinnatifida and Porphyra umbilicalis in meat products as well as in cereal based products. Application of fucoxanthin, from U. pinnatifida on ground chicken breast resulted in decreased TBARS value (Sasaki et al., 2008). The effect of carotenoid pigment, fucoxanthin on lipid peroxidation and meat colour in ground chicken breast using U. pinnatifida was studied and resulted decrease in the TBARS value along with decreased L* value and increased a* and b* values thereby presenting its potential to be used as an ingredient for the improvement of the appearance and shelf life of chicken meat and its products (Sasaki et al., 2008).

A study was conducted by Athukorala et al. (2005) to assess the antioxidant activities of G. filicina extract using linoleic acid and fish oil as substrates at 65°C for 168 hrs which resulted in delayed onset of oxidation. In addition, Siriwardhana et al. (2004) reported that the antioxidative effect of H. fusiformis methanolic extract on fish oil and linoleic acid was superior to BHT and BHA. In addition, study by Devi et al., 2011 to assess the reducing power, antioxidant activity and total phenolic content of crude methanol as well as diethyl ether extracts of Indian seaweeds i.e. Halimeda tuna, Turbinaria conoides and Gracilaria foliifera was done and reported highest total phenolic content and total antioxidant activity of 1.231 mg GAE/g and 1.675 mg GAE/g respectively in T. conoides extract. Thus, it can be concluded that seaweeds are promising alternatives to replace synthetic antioxidants by providing an environmentally safe and nontoxic source to use in functional foods and pharmaceutical industries. Andrade et al. (2013) examined the bioactive compounds from 18 macro-algae in ethanol extracts using gas chromatography-mass spectrometry (GC-MS) off the Portuguese coast. Indian brown seaweed, Sargassum marginatum incorporated pasta was developed by Prabhasankar et al. (2009) and reported that with the increase in concentration of seaweed the reducing power of pasta improved and DPPH radical scavenging activity of seaweed-incorporated pasta was higher in cooked form as compared to raw one. Pindi et al. 2017 studied the effect of incorporation of Kappaphychus alvarezii in chicken sausages as an antioxidant source containing 2%, 4% and 6% Kappaphychus alvarezii during chilled storage and found that the presence of seaweed powder reduced L* i.e. lightness and increased a* i.e. redness with better physicochemical properties compared to the control. The effect of laminarin and fucoidan fortification at different concentration (0.01%, 0.1%, and 0.5%) on the quality characteristics of fresh and cooked pork patties was studied by Moroney et al., 2013 and reported that the lipid oxidation was reduced in fucoidan compared to laminarin fortified pork patties. This can be attributed due to higher free radical scavenging activity (i.e. presence of anionic sulphate group) of fucoidan.

Moreover, utilizing the synthetic antioxidants is correlated with probable toxicity as well as side-effects, like carcinogenesis (Dellarosa et al. 2015), besides, due to consumer awareness and demand towards selection of food fortified with natural and organic source the use of artificial or synthetic antioxidants has declined. Still, only a few natural food antioxidants are commercially available on the market. Hence, seaweeds and their extract can be used in convenience food, functional foods, value added foods, imitated foods in order to increase their stability and antioxidant potential.

Various forms of seaweed utilization:

Seaweeds can be utilized in various form, right from consuming in raw form to formulation of meat products along with dairy, bakery and confectionary products. Apart from food industry it has wide acceptance in bioengineering (biofuel, bio-plastics, etc.), pharmaceuticals, cosmetics and chemical industry. A pictorial representation is provided below to understand the wide array of seaweed utilization.

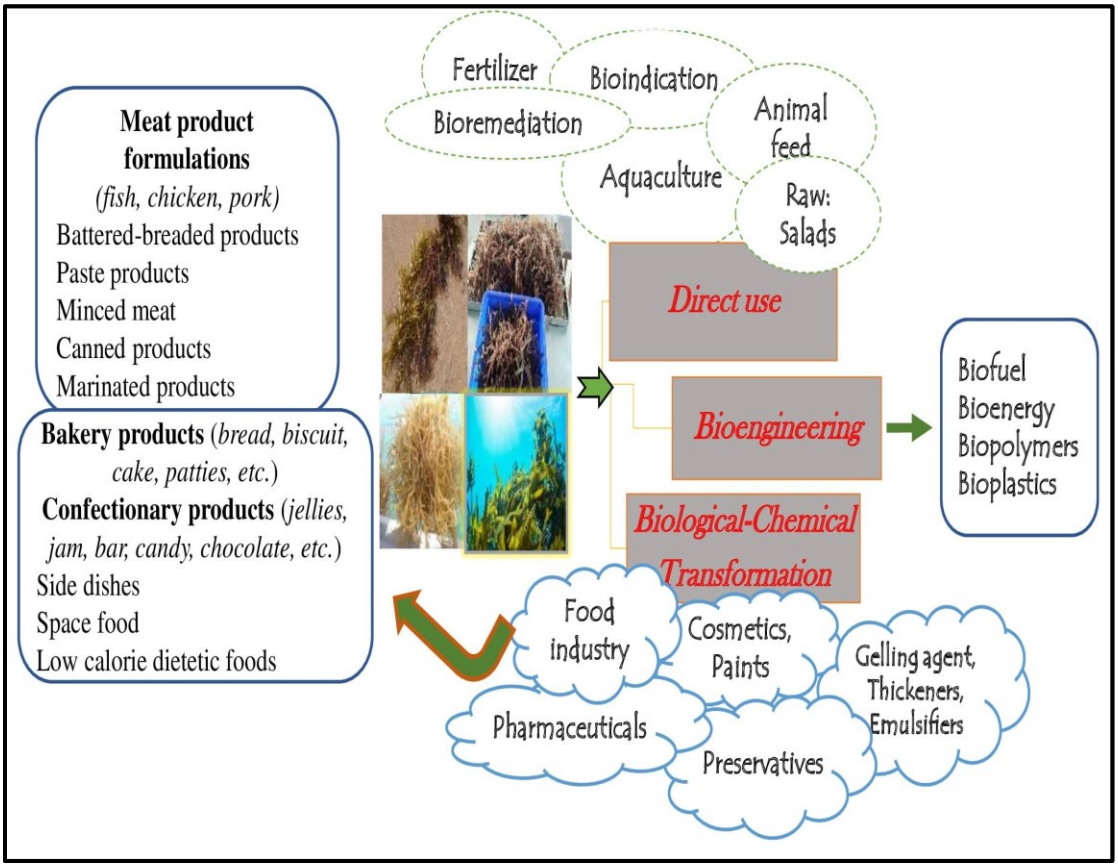

Fig 2. Utilization of Seaweed resources

Antimicrobial action of seaweeds extracts and their addition to food

Seaweed extracts are often regarded as interesting natural sources with potent antimicrobial properties (Pinteus et al., 2015). Expression of antimicrobial activity possessed by either natural extract or synthetic compound is usually clear, but the mechanism for this action is only moderately understood. The phenolic compounds attack the organism's cell wall and

membrane thereby results in the release of intracellular constituents and possess numerous invasive targets which could lead to the inhibition of bacteria. In addition, interfere with the membrane functions such as electron transport disruption, uptake of nutrient and protein, synthesis of nucleic acid along with enzyme activity (Bajpai et al., 2007; Schulz et al., 1992). A continuous focus is developed towards seaweed and their extracts in the direction of their use as a sources of natural products with antimicrobial activities for the treatment of many infectious diseases and is well deliberated (Abu-Ghannam et al., 2013, Safhi, 2014). The expansion of drug resistant pathogens is a momentous threat towards successful treatment of microbial diseases, thus, exploring new molecules and extracts with potential antimicrobial activities is pursued (Himejima & Kubo, 1991).

Phloro-tannin extracts are potent pharmacological substitute for treating wide array of microbial infections (Lopes et al., 2013). Phlorotannins interaction with bacterial proteins possibly plays an important role in the bactericidal action of phlorotannins (Nagayama et al., 2002) and the mechanism appears similar to terrestrial tannins comprising inhibition of extracellular bacterial enzymes, deprivation of growth substrate or direct inhibition of oxidative phosphorylation (Wang et al., 2009). The antimicrobial action of seaweed based bioactive compounds like terpenes, phenols against various gram positive and negative bacteria is very well documented (Kim et al., 2008, Gupta et al., 2010). Ultrasound-assisted laminarin showed marked inhibition of bacterial growth against S. aureus, L. monocytogenes, E. coli, and S. typhimurium (Kadam et al., 2015).

1, 8-dihydroxy- anthraquinone isolated from the red algae Porphyra haitanensis showed strong inhibition of the cell growth in the logarithmic phase towards S. aureus (Wei et al., 2015). It pointed for further investigation of 1, 8- dihydroxy-anthraquinone as a natural seaweed product in food safety control and drugs. Kolsi et al., 2015 found strong antimicrobial activities of organic extracts (hexane, ethyl acetate, methanol) obtained from various species pheophytea, chlorophytea and magnoliophytea of investigated the antibacterial and fungicidal activities of marine macroalgae and magnoliophytea from the Tunisia coast against human pathogenic bacteria, yeast and fungi (Escherichia coli, Listeria monocytogenes, Salmonella enterica, Agrobacterium tumefaciens, Pseudomonas aeruginosa, S. aureus, Micrococcus luteus, Saccharomyces cerevisiae and Aspergillus niger). Three extracts from five pheophytea, five cholorophytea, and three magnoliophytea species were prepared using hexane, ethyl acetate and methanol and the results revealed strong antimicrobial activities in all the extracts with maximum in brown algal extract and this can be used to treat certain human diseases. In addition, the ethanolic extract of Gracilaria fisheri has shown immuno-stimulant and anti-microbial activity against V. harveyi in Peneaus monodon (Kumaran et al., 2010).

Laminarin at 0.1% inhibited 70-90% adhesion of L. monocytogenes, S. typhimurium and V. parahaemolyticus to human enterocyte like HT-29-Luc cells (Kuda et al 2015). Nagayama et al 2002 reported an MBC (Minimum bactericidal concentration) of 0.79 μmol/ mL with E. kurome against Campylobacter jejuni. Furthermore, antibacterial activity of E. cava against

Staphylococcus aureus and Salmonella strains at MIC (Minimum inhibitory concentration) values of 125–250 µg/mL were reported by Choi et al. 2010. In addition, eckol and ampicillin in combination showed synergistic and additive effect (Choi et al. 2010). Kim et al. (2010) tested the toxicity of fucoidan in Sprague-Dawley rats (1350 mg/kg, bw/day) for 4 weeks and observed no significant differences in groups matched by gender in relation to body weight, urinalysis, ophthalmoscopy, hematology as well as histopathology. Additionally, the toxicity studies carried out by Vidal et al. (1984) on two metabolites of Caulerpa spp. i.e. caulerpin and caulerpicin and found that the 2 metabolites are non-toxic. Terpenoids like mertensene, violacene (Argandona et al., 2000), aplysiaterpenoid A, elatol, etc. (Bianco et al., 2013) have not been verified with toxicological studies till yet hence their safety profile in vitro and on animal species can be studied well. Markable inhibitory actions on antiinfluenza A virus (IAV) both in vivo and in vitro by carrageenan and its sulphated derivatives was reported by Wang et al (2012). Kappa/iota carrageenan possessed strong potential anticoagulant activity in low concentration and this is mainly due to the monosaccharide composition along with the position, number and distribution of sulphate groups along galactan chain (Yermak et al. 2012).

Seaweed as Polysaccharide or dietary fibre source

Marine seaweeds are ample source of numerous bioactive compounds including polysaccharides representing diversity in cell wall and structural polysaccharides in monosaccharide composition, configuration (absolute and anomeric), linkages i.e. glycosidic linkages, molecular mass and the availability of functional groups. Cell wall of seaweed is mainly comprised of polysaccharides accounting approximately 50% of dry weight basis (Stiger-Pouvreau et al. 2016) varying in the biochemical composition with species and environmental factors too (Rioux and Turgeon, 2015). Fucales and Laminariales family of brown seaweed contains Laminarin, a storage polysaccharide moreover, sulphate group containing polysaccharides namely sulphated polysaccharides like ulvan, fucoidan, carrageenans are present in green, brown and red seaweeds respectively (Costa et al., 2010). They are extracted from raw material and later purified either by preparative chromatographic techniques or chemical treatments. Algal/seaweed matrix cell wall polysaccharides can be labelled as phycocolloids or phycohydrocolloids due to good water solubility which creating a colloid system in aqueous media forming gels and films with suitable conditions (i.e. negatively charged groups, intramolecular and intermolecular junctions/linkages and their interactions), mostly the films are formed by solution casting and solvent evaporation (Lahaye, 2001). These have a wide range of application in biological as well as biomedical field due to their bio availability and bio compatibility (Venkatesan et al, 2015 b).

The total dietary fibre in most of seaweeds is slightly higher than the terrestrial plants, it varies between 33-62% (dry weight basis) and are rich in soluble fractions (Dawczynski et al., 2007; Lahaye, 1991). Addition of seaweed as a functional ingredient helps to overcome certain scientific/technological glitches associated with low-salt meat products along with imparting the nutraceutical advantages and thereby popularizing seaweeds in diet among non-seaweed

consuming population. Moreover, polysaccharides in seaweed possess various biological activities along with providing the textural properties (Balboa et al., 2013). In addition, they provide plentiful hydrocolloids located in the cell wall and their content is influenced by several factors like harvest period, species, extraction method, etc. having significant impact on the functional properties of polysaccharides (Rioux & Turgeon, 2015) and are usually employed for stabilizing emulsions, viscous behavior, gelation, suspensions and foams and controlling crystal growth (Chapman, 2012). The key hydrocolloids are agar, alginates, and carrageenan. Agar has been used since the 17th century in Japan (Armisen, 1995) and is chiefly extracted from Gelidium and Gracilaria (McHugh, 2003). The cell wall of Gelidium and Gracilaria hold around 20-30% and 15-20% of agar, respectively (Freile-Pelegrín et al., 1995). It is principally used for its thickening and gelling properties. Carrageenans, commonly identified as carbohydrate antigens, has the potency to promote the growth of connective tissues. Chondrus crispus and Gelidium cartilagineum yields agar and carrageenan in higher concentrations. The most extensively produced algal polysaccharides are alginates, also known as alginic acid or algin. They are extracted from the cell walls of brown seaweeds (Kohajdová & Karovičová, 2009) and are mainly composed of 1,4-β-D-mannuronic acid and α-L-guluronic acid. This composition may differ from species to species. Unlike agar, alginates do not melt at high temperatures, and form cross linked gels002E

Conclusion

Seaweed stands as relative unexplored novel molecules for their utilization as functional foods and nutraceuticals. However, narrow market niche coverage can be seen for seaweed-based functional food, still their success is awaited, hence, fortifying the foods of high consumer acceptance with seaweed bioactive compounds can offer an opportunity to disseminate health benefits of seaweeds. Although immense literature is available on the bioactive properties of seaweeds, only few studies were conducted on their candid use in food products. Therefore, this area needs to be well researched to assess the full nutritive potential of seaweeds.

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Innovations in Fishery Engineering

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Introduction

Major areas of technological interventions in the field of fishery engineering include the design and development of fish processing equipment and machinery, 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 include the development of cost-effective solar dryers with LPG, biomass, Infrared or electrical backup heating systems, fish de-scaling machines, Fish freshness sensors, etc. Post-harvesting processing of fish is important to reduce 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 in subsequent sections.

Solar dryers

Fisher folks catch fish as major aquatic products to sell in the local market, and in case of over catch tremendous losses occur due to inadequate cold chain management facilities in developing countries. Alternatively, the fisherman could convert the excess catch of fish into a value-added product *i.e.* dried fish. For example, In India, about 20-30% total catch of fish is dried for export and or local consumption. Drying preserves fish from decay by removal of moisture from fish, thereby arresting the growth of bacteria, the action of enzymes, and the chemical oxidation of the fat. Open-air sun drying is the traditional method employed by fisherfolks in India to dry fish and 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. However, it often results in inferior quality of product due to its dependence on weather conditions and vulnerability to the attack of dust, rain, insects, pests, and microorganisms. Also, it requires a longer drying time (Murali et al. 2019).

Solar drying is an alternative that offers numerous advantages over the traditional method and is environmentally friendly and economically viable in developing countries. In solar drying, a structure, often of very simple construction, is used to enhance the effect of solar radiation. Compared to 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 products. However, there exist some problems associated with solar drying i.e. reliability of solar radiation during a rainy period or cloudy days and its unavailability during nighttime. 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 a backup heat source and also by storing the energy in the form of sensible or latent heat during sunshine hours. In this way, drying becomes a continuous process and the product is saved from possible deterioration by a microbial infestation. These types of hybrid solar dryers find useful applications in developing countries where conventional energy sources are either scarce or expensive and the heat-generating capacity of the solar system is not sufficient.

The design of solar dryers varies from simple direct dryers to more complex hybrid designs. Hybrid model solar dryers are having LPG, biogas, biomass, or electricity as alternate backup heating sources for the continuous drying of fish even under unfavorable weather conditions. ICAR-CIFT has developed different models and capacities of solar dryers for the hygienic drying of fish. The capacity of these hybrid solar dryers varies from 6 to 110 m^2 of tray spreading area for drying various quantities of fish varying from 10 kg to 500 kg.
The labor requirement is considerably reduced compared to open sun drying in beaches/coir mats because of the elimination of the cleaning process due to sand and dust contamination. The re-handling process like spreading, sorting, and storing because of non-drying or partial drying due to unfavorable 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 fetch higher income for the fisherfolk. The eco-friendly solar drying system reduces fuel consumption and can have a significant impact on energy conservation.

ICAR-Central Institute of Fisheries Technology (CIFT), Cochin, has already developed low-cost, energy-efficient, and eco-friendly dryers like Solar cabinet dryers, Solar tunnel dryers, Infrared dryers, etc for uniform and hygienic drying of fishes (Fasludheen et al. 2017). These dryers are also suitable for drying agricultural products like fruits, vegetables, spices, and condiments.

1.1. Solar dryer with LPG backup (50-60 kg)

ICAR-CIFT designed and developed a novel system for drying fish using solar energy supported by environment-friendly LPG backup (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 backup heating system will be automatically actuated to supplement the heat requirement. Water is heated with the help of solar vacuum tube collectors installed on the roof of the dryer and circulated through heat exchangers placed in the PUF-insulated stainless steel drying chamber. 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 fish, fruits, vegetables, spices, and agro products. It helps to dry the products faster than open drying in the sun, by keeping the physicochemical qualities like color, taste, and aroma of the dried food intact and with higher conservation of nutritional value. A 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 on energy conservation (Murali et al. 2020; Murali et al. 2021).

Fig.1. ICAR-CIFT Solar-LPG hybrid dryer

1.2. Solar dryer with electrical backup (20 kg)

Effective solar drying can be achieved by harnessing solar energy from 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 hygienically. Since the drying chamber is closed, there is less chance of material spoilage by external factors. An alternate electrical backup heating system under controlled temperature conditions enables the drying to continue even under unfavorable weather conditions like rain, cloud, non-sunny days, and night hours so that bacterial spoilage due to partial drying will not occur. Improved shelf life and value addition of the product fetch higher income for the fisherfolk. The eco-friendly solar drying system reduces fuel consumption and can have a significant impact on energy conservation.

Fig. 2. ICAR-CIFT Solar-electrical hybrid dryer

1.3. Solar dryer with electrical backup (40 kg)

The dryer consists of four drying chambers with nine trays in each chamber (Fig. 3). The trays made of food-grade stainless steel are stacked one over the other with a 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 backup comes into a role once the desired temperature is not attained for the drying process, particularly during rainy or cloudy days.

Fig. 3. ICAR-CIFT Solar-electrical hybrid dryer

1.4. Solar tunnel dryer

This dryer can be used by fishermen or small-scale fish processing units for bulk drying during seasonal higher catch/excess landing of fish. The capacity of the solar tunnel dryer is 50 kg with a floor area of 12 m^2 (Fig. 4). The materials of construction are UV-stabilized transparent polythene sheet for the roof cover, black absorber sheet for the floor, supporting frames of CPVC, and GI rod. Three ventilator fans of 0.5 hp were provided for air inlet and moisture removal. The trays with tray holders were placed inside the dryer for spreading and hooking the fish for drying. This tent dryer was designed as a stand-alone system as it does not require any external power source/electricity. The fans were operated through a solar PV panel fitted on the rooftop of the dryer and associated battery setup. It is also affordable and suitable for Indian fisherfolk.

Fig. 4. ICAR-CIFT Solar-tunnel dryer

1. Fish Descaling Machines

2.1.Fish descaling machine with variable drum speed

The fish de-scaling machine is designed and fabricated for removing the scales of fish easily. This equipment can remove scales from almost all types/sizes/ species of fishes ranging from marine to freshwater species like Sardines, Tilapia to Rohu. The machine is made of SS 304 and has a 10 kg capacity (Fig. 5). 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 load. The drum is made of a perforated SS 304 sheet fitted in a strong SS Frame. A 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 the removal of scales. The water outlet is also provided to remove scales and water from the machine. An Electronic RPM meter was attached to the de-scaling machine which directly displays the RPM of the drum. The speed of the drum is a factor influencing the efficiency. The machine takes only 3-5 minutes to clean 10 kg of fish depending on the size.

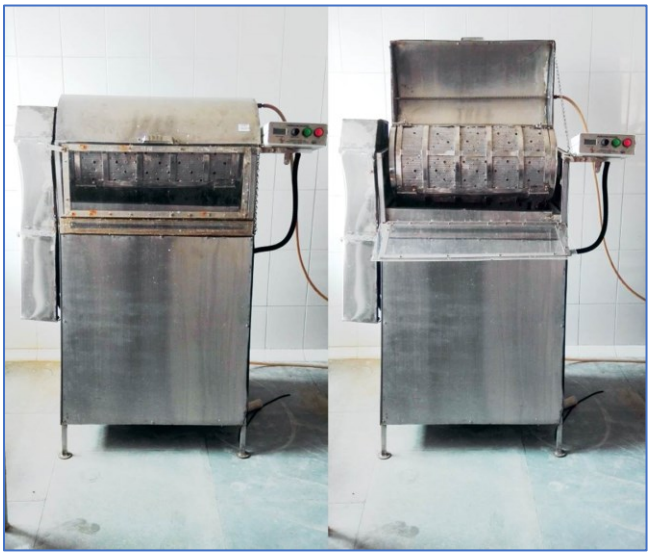

Fig. 5. Fish de-scaling machine with variable drum speed

2.2.**Fish de-scaling machine with fixed drum speed- tabletop**

The fish de-scaling machine is designed and fabricated for removing the scales of fish easily. This equipment can remove scales from almost all types/sizes/ species of fishes ranging from marine to freshwater species like Sardines, Tilapia to Rohu. This machine is made of SS 304 and has a 5 kg capacity. It contains a 0.5 HP AC motor with a proper belt reduction mechanism to achieve the required drum speed of 20-30 rpm. The body is fabricated in dismantling type one-inch square SS tube with a suitable covering in the electrical parts (Fig. 6). The drum is made of a perforated SS sheet fitted in a strong SS Frame having suitable projections to remove the scale and provided with a leak-proof door with a suitable lock.

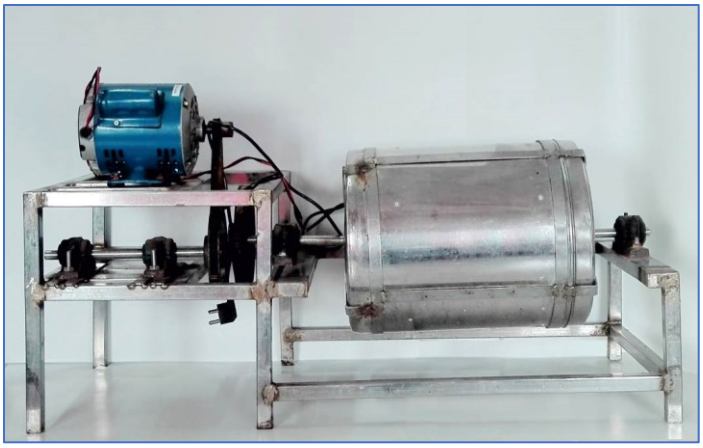

Fig. 6. Fish de-scaling machine with fixed drum speed

2.3. **Hand operated Fish descaling machine**

The fish descaling machine is designed and fabricated for removing the scales of fish 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 a 5 kg capacity. The body is fabricated by dismantling a type 1-inch square SS tube. The drum of 255.5 mm diameter and 270 mm length is made of a perforated SS sheet fitted in a strong SS Frame having suitable projections to remove the scale and provided with a leak-proof door with a suitable lock. A pedal is fitted on the side to rotate the drum manually (Delfiya et al. 2019).

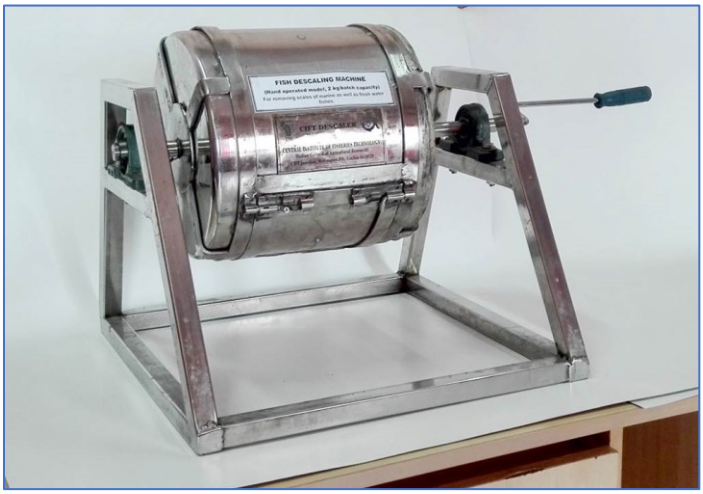

Fig. 7. Hand-operated fish de-scaling machine

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 (Fig. 8). 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 customized for specimens during the 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 utilizing specimens other than

for which the yield has been originally customized. The meat yield of this machine was about 60% against 35% in imported models. The capacity of the machine is 100 kg/hour.

Fig. 8. Fish meat bone separator

4. Refrigerated Mobile fish vending kiosk

ICAR-CIFT has designed and developed a mobile fish vending kiosk for selling fish in the closed chilled chamber under hygienic conditions at the consumer's doorstep. The mobile unit is mounted on a frame with wheels at the bottom. The kiosk can carry 100kg fish with 20kg under chilled storage display in a glass chamber and remaining in an insulated icebox. The main components of the kiosk are; a fish storage & display facility, a hand-operated descaling machine, and a fish dressing deck with a washbasin, water tank, cutting tool, waste collection chamber, and working space. The vending unit has been fabricated using stainless steel (SS 304 Food Grade. The stored fish is covered with a transparent glass cover through which consumers can see the fish and select according to their choice of purchase. A kiosk is attached with a hand-operated descaling machine for the removal of scales. The fish coming out of the de-scaler is free of scales, dirt, or slime. It also reduces human drudgery and avoids cross-contamination, consuming lesser time. The fish dressing deck with washbasin is also designed conveniently to prepare fresh clean fish under hygienic conditions. The unit also extends the keeping quality of fish for 4- 5 days and increases the marginal benefit to fish vendors. It also helps change the practice of unhygienic handling and marketing of fish.

Fig. 9. Refrigerated mobile fish vending kiosk

5. Electronics and Instrumentation

ICAR-CIFT identified the vast scope of electronics and instrumentation for fishery's 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 machinery used for harvesting the resources and post-harvest technology. Basic technologies developed in ICAR-CIFT include more than five dozen 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 the 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 with 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, shipborne data acquisition system, water level recorder, ocean current meter, remote operated soil moisture meter, water activity meter, rheometer, and microalgae concentration monitor. Since the instruments are designed to be compatible with the computer and solid-state memory module, the information can be stored for a long duration and retrieved at our convenience.

By effective use of efficient and appropriate engineering technologies which are cost-effective, adaptable, and environment friendly, the fishermen community, as well as the 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 footprints.

6. Energy and Water Use Optimization in Seafood Processing Industry

In the seafood industry, the increasing importance to ensure effective usage of energy and water needs the implementation of sustainable technologies and cleaner production practices. The review findings report that the replacement of outdated technologies, the use of renewable energy sources, and creation of awareness about energy consumption among manpower, and continuous energy auditing results in effective energy usage in the seafood processing sector. Similarly, adopting water optimization techniques such as automation of water flow lines, wastewater treatment, recycling and recirculation of water, continuous monitoring of water use patterns, and dry-cleaning process in the industry would result in water savings. The smart cloud-connected intelligent real-time energy and water use monitoring systems could be considered suitable methods to optimize energy and water usage in the seafood industry. The application of software using the Internet of things (IoT) can help analyze the daily, weekly, monthly, or yearly consumption pattern. Mobile alert systems can be installed for giving warnings regarding peak-specific energy consumption. Besides, developing new applications of byproducts and generating energy from waste can reduce waste disposal and environmental pollution issues in the seafood sector. It is also important to understand the nexus between energy, water, and seafood from the environmental and sustainability perspective. Each of these three sectors has an impact on the security of others in a variety of ways. The authors observed that additional studies should be carried out on the entire seafood supply chain, starting from harvesting to consumption for the sustainability of the whole sector. The government authorities should provide tax benefits and other financial incentives for individuals and seafood firms for being eco-friendly with the effective management of energy and water with the generation of minimum waste and GHG emissions. The government should also form a committee of assessors for the periodic evaluation of seafood processing firms to improve their competence while being sensitive to socio-economic and environmental implications.

7. Commercialization of engineering technologies

A more pragmatic system for business incubation and promoting start-up companies concerning agricultural technologies have been evolved in recent times within the ICAR-CIFT.The Agri-Business Incubation (ABI) center along with Institute Technology Management Unit (ITMU) seeks to provide business consulting services to agriculture-related businesses and helps to develop a strategic business plan. ABIs facilitate for incubation of new business ideas based on new agricultural technologies by providing cheap space, facilities, and required information and research inputs. The Agribusiness Incubator Program also seeks to provide business consulting services to agriculture-related businesses and helps to develop a strategic business plan.

The Engineering Division of ICAR-CIFT has commercialized its technologies like solar fish dryers, fish descaling machines, refrigeration-enabled fish vending machines, etc through the ABI.

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Antimicrobial Resistance (AMR) in aquatic products

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Introduction

Among the animal food production sector, aquaculture represents a large share of the global antimicrobial consumption as the industry shows an unprecedented growth by means of intensification. India experienced an eighteen-fold increase of fish production within the past seven decades with the annual increase of 0.75 million metric tons in 1950-51 to 14.16 million metric tons in 2019-20 (Handbook on Fisheries Statistics, 2020). Globally, the country now takes the second position, after China, with regard to annual aquaculture production (FAO, 2020). Indian marine product exports witnessed impressive growth from 37,175 tonnes in 1970 to 12,89,650.90 tonnes in 2019-20 and the frozen shrimp continued to be the main export value item accounting for a share of 74.31% of the total US$ earnings of which the contribution of cultured shrimp is 90% (http:/www.mpeda.com). Thus the aquaculture industry showed exponential growth by means of super intensive culture practices. But this expansion and intensification of aquaculture farming is causing severe stress and the cultured species are becoming susceptible to many diseases. This is the most common reason for the use of animal drugs in aquaculture. Globally, antimicrobial consumption in aquaculture in 2017 was estimated at 10,259 tons, with Asia-Pacific region being the largest consumer of antimicrobials, and it is projected to increase 33% by 2030 (Schar *et al*., 2020). FDA approved drugs used in aquaculture are listed in Table1 (https://www.fda.gov/animal-veterinary/aquaculture/approved-aquaculture-drugs). Unfortunately antibiotic use is now an integral part of intensive farming and is widely practiced as growth promoter and prophylaxis measures. Some commercially available growth enhancing feedmix containing antibiotics are listed in Table 2 (Bhushan *et al*., 2016). The use of antibiotics to treat the infected fish in the whole farm leads to the development of resistance in the microbial population of the aquaculture production system including the beneficial microbes. The term 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. The main mechanism of resistance to antimicrobial agents may fall under any one of these categories: changes in the bacterial cell wall permeability or target sites, enzymatic drug modifications or degradation, or and efflux of drugs with the help of membrane bound pumps (Reygaert, 2018).

Second important issue concerned with the imprudent usage of antibiotics is the direct harmful effect of the drug residues in humans causing allergy, Gastro-intestinal disorders, genotoxicity, cancer etc. For example, chloramphenicol (CAP) residues cause myelosuppression and CAP –induced aplastic anemia (Hanekamp and Bast, 2015), likewise nitrofurans and their metabolites have non-neoplastic effects, genotoxicity and carcinogenicity (EFSA Panel on Contaminants in the Food Chain (CONTAM), 2015). The aqua farmers also use veterinary drugs since no specific antibiotics are prescribed for aquaculture system. But the problem of veterinary antibiotics in shrimp is a cause of major concern in the Indian shrimp export sector. The 1995 Prevention of Food Adulteration Act & Rules (Part XVIII) regulates amount of antibiotics in aquaculture and residue tolerances in

shrimp and fish tissue (Bhawan N, 2011). The antibiotics and other pharmacologically active substances banned for use in shrimp aquaculture by Coastal Aquaculture Authority (CAA) are chloramphenicol, nitrofurans, neomycin, nalidixic acid, sulfamethoxazole, dimetridazole, metronidazole, ronidazole, ipronidazole, other nitroimidazoles, sulphonamide drugs, fluroquinolones, glycopeptides, clenbuterol, diethylstilbestrol, chloroform, chlorpromazine, colchicine, dapsone and aristolochiasp and preparation thereof (http://caa.gov.in/uploaded/doc/Pharmacologically.pdf). Export inspection council of India provides specifications for maximum residual limits (MRLs) for antibiotics in fish and fishery products; 0.1pmm for tetracycline and OTC, 0.3 ppm for oxolinic acid, 0.05 ppm for trimethoprim and zero tolerance to CAP, Furazolidone, Neomycin, Nalidixic acid, and Sulphamethoxazole. However, for export, the residual levels are fixed by individual countries for specified products (www.eicindia.gov.in).

Evidence of Antibiotic residues and bacterial pathogens in fishery products exported to European Union (EU) and United States (US)

During 2015 to 2020, a complete of 141 Rapid Alert System for food and feed (RASFF) notifications associated with fishery exports from India to EU (46), USA (66), and Japan (29) were notified (MPEDA, 2020). The major quality issues in the exported fishery products (Crustaceans, Cephalopods and Finfish) were veterinary antibiotics (>50%), heavy metals (~15.0%), and pathogenic microorganisms (~10.0%). The residues of veterinary medicines detected in fishery products were Furazolidone (AOZ), Nitrofurazone (SEM), Oxytetracycline (OTC) and CAP and the major pathogenic bacteria included Vibrio species (Vibrio cholerae/ V. cholerae non-O1/ non-139, V. parahaemolyticus, V. vulnificus) and Salmonella species (Salmonella Paratyphi B, and S. Weltevreden) (Madhusudhana Rao et al., 2017). So, the EU has established a minimum required performance limit (MRPL) of 1 µg/kg (1 ppb) for Nitrofuran metabolites and 0.3 µg/kg for chloramphenicol in aquaculture products. However, the EU has zero tolerance to Nitrofurans which suggests 'any confirmed concentration of any of the metabolites may be a non-compliance'.

Use of antibiotics in aquaculture and its impact on bacterial pathogens

The majority of the detected bacterial pathogens in aquatic products aren't a native flora of fish. It clearly indicates that the major source of these pathogens is the whole production chain viz., contact of the aquatic products to the environment where they're grown, various implements used, contact surfaces, handlers, water etc. The post-harvest handling process plays a major role in the aqua product contamination with the human pathogens such as Escherichia coli, Staphylococcus aureus, Salmonella spp., V. cholerae, V. parahaemolyticus, Listeria monocytogenes, Shigella spp., Aeromonas hydrophila, Plesiomonas shigelloides and viral pathogens such as hepatitis A virus etc. (Novoslavskij, 2016). Among these pathogens, E. coli, S aureus, Salmonella spp., and Shigella spp. are non-indigenous to the aquatic environment. Depending on the character of the environment (contaminated water), feeding habits (filter feeders), season of harvest (summer) are considered as crucial factors for the contamination of aquaculture products. In addition, the danger is potentiated not only by the presence of those pathogens but also by the presence of antibiotic resistance in them.

Worldwide research deviation is noticed on antibiotic resistant pathogens both from the clinical sector and within the food producing animals.

The major antibiotic-resistant pathogens of clinical importance are Methicillin-resistant S. aureus (MRSA), Extended-spectrum Beta-lactamase (ESBL) producing Enterobacteriaceae, carbapenem-resistant Enterobacteriaceae (CRE), Vancomycin-resistant Enterococci (VRE), Acinetobacter baumannii and so on (Kraemer et al., 2019). The link between the use of antibiotics in aquaculture production and the presence of antibiotic-resistant foodborne pathogens has been already reported by various researchers. Many reports are available for the presence of virulent MRSA from retail food fishes (Sivaraman et al., 2016, 2017 2021a, 2021c; Muneeb et al., 2021), seafood and environments (Murugadas et al., 2017a, 2017b, 2019), and shrimp aquaculture farms (Rajan et al., 2021). Likewise, the presence of ESBL E. coli and Klebsiella pneumonia have been detected from retail food fishes (Sivaraman et al. 2020a, 2020b), and shrimp farms (Sivaraman et al., 2021b). Table 3 shows available reports of antibiotic resistant bacteria associated with fish from India. This perhaps shows the importance of studies on AMR pathogens in food-producing animals with special reference to the development of seafood or aquatic products. In general aquaculture products have the close proximity of getting contaminated to various microbes during the entire production and processing chain. Raw foods in general have the highest culturable bacterial loads, followed by minimally and fully processed foods. The food with acceptable microbiological loads (5 lakh and 1 lakh CFU/g for raw and processed aquaculture products) (Rao et al., 2018) can also function as a sink for the event of antibiotic resistances through bacteria, bacteriophages, bacterial DNA and mobile genetic elements etc. Hence, the food chain ecosystem may be conducive niches for gene transfer, antibiotic selection pressure and persistence of AMR bacteria and this route cannot be disregarded.

Antimicrobial-resistant pathogenic bacteria are released into aquatic environments through wastewater and act as potential spread of antibiotic resistance genes. Many studies show that the trend of antibiotic resistance is changing depending on the country of origin of the seafood and antibiotic usage in a specific country for aquaculture practices etc., (Murugadas and Ezhil, 2017). Laboratory detection of AMR in bacterial pathogens phenotypically and genotypically is key to monitor the situation and to develop effective action plans. Now-a-days there is a shift in the adoption of methodologies for determination of antibiotics resistances, with genotypic methods being implemented at a high throughput level for better understanding of molecular mechanisms of antibiotic resistance.

Controlling of AMR

Already the US and EU have put a control measure to counteract AMR based on the principle of quality management and process-oriented controls throughout the food chain. Implementation of hygienic practices must be verified and certified by the national authorities. Each and every personnel who are involved in the seafood production chain is responsible to interrupt the chain of contamination and spread of the AMR pathogens. WHO, FAO and OIE have taken a collective tripartite joint venture called ‘one health’ approach to control AMR spread which is considered as national action plans to each country. India established a

national plan on AMR (NAP- AMR; 2017-21), regarding standardization and guidelines for the use of antibiotics. Food safety and standard authority of India (FSSAI) also launched food safety audits and certification in the Indian meat industry. All these actions may be helpful for the restricted use of antibiotics in the animal food production sector. Other mitigation measures proposed to control AMR include strengthening the surveillance of antibiotic usage and AMR pathogens in healthcare, food producing animals and environment, strengthening the laboratory capacity for surveillance system, formulating regulations for the optimized use of antibiotics in human and animal health, creating awareness and understanding among the general public, effective infection prevention and control programmes, development of alternatives to antibiotics, arranging awareness campaigns in farming areas, monitoring hatchery operations, promoting sustaining aquaculture using natural alternatives, promoting best management practices throughout the culture period, and hazard analysis in each step of the food production and transportation chain etc.

Conclusion

AMR is an increasing global public threat, with rapid emergence of newer resistances and faster spread across countries. This results in prolonged illness, complications in surgical conditions due to infection with resistant organisms, severe fatal forms etc. Antibiotic resistance development is a natural action over an extended time; however, the current situation is happening at an elevated speed due to various reasons such as the misuse and overuse of antibiotics as growth-promoter in food-producing animals, improper surveillance and regulation of the utilization of antibiotics etc. AMR organisms are present in human, animal, food, and the environment which make the transmission faster between or within humans and animals. AMR is a complex and interdisciplinary issue, holistic efforts and multisector approach is required to bring down the burden of AMR in public.

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Further reading

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Table 1. List of FDA approved animal drugs used in aquaculture (Grant, 2021 https://www.fda.gov/media/80637/download)

Sl. No	Drug	Proprietary Name	Route o administration	Indication for Use
1	Florfenicol	Aquaflor®	Medicated Articles/ Feeds	**Warmwater Finfish**- control of streptococcal septicemia associated with *Streptococcus iniae*. • **Salmonids**- control of mortality due to coldwater disease associated with *Flavobacterium psychrophilum* and furunculosis associated with *Aeromonas salmonicida.* • **Finfish**- control of mortality due to columnaris disease associated with *F. columnare*.

				➢ **Catfish**- control of mortality due to enteric septicemia of catfish associated with *Edwardsiella ictaluri*.
2	Oxytetracycline dihydrate	Terramycin®		• **Salmonids**- control of ulcer disease caused by *Haemophilus piscium*, furunculosis, bacterial hemorrhagic septicemia caused by *A. hydrophila*, and pseudomonas disease. • **Catfish**- control of bacterial hemorrhagic septicemia caused by *A. hydrophila* and pseudomonas disease. • **Lobster**- control of gaffkemia caused by *Aerococcus viridans*. ➢ **Pacific Salmon**- For marking of skeletal tissue. ➢ **Freshwater-reared salmonids** weighing up to 55 gram-For marking the skeletal tissue

3	Sulfamerazine	Sulfamerazine		➢ **Trout**- control o furunculosis
4	Ormetoprim/ Sulfadimethoxine combination	Romet-30®		➢ **Catfish** - control o enteric septicemia ➢ **Salmonids**- control o furunculosis

Table2. List of some commercially available growth promoter containing antibiotics (Bhushan *et al*., 2016)

l. no	**Feedmix**	**Antibiotics present**	**Dose**	**Benefits**	**Produced Company**
	Oxy-100-FS	Oxytetracycline	-	➢ Growth promoter	Neospark
	DOX-ADD	Doxycycline (2%)	1-2 kg/ton of feed (7-10 days)	➢ Prevents and controls all kinds of bacterial diseases ➢ Increases growth and body weights	Advanced Aqua Biotechnologies
	ADDCIP-M	Ciprofloxacin(25g) Metronidazole (25g)			
	FURZAZ-20	Furazolidone (20%)			
	OXYTREAT-5	Oxytetracycline hydrochloride (10%)			
	DOX-KZ	Doxycycline hydrochloride	1-2 kg/ton of feed (7-10 days)	➢ Prevents and controls all kind of bacterial diseases ➢ Improves digestion & absorption of nutrient	Kaizen Biosciences
	OXYTREAT-10	Oxytetracycline			
	FURA TREAT-20	Furazolidone (20%/ 200gm)			

				s by reducing the bacterial load in the gut Increases growth and body weights	

Table 3. Antibiotic resistant bacteria associated with fish (Reports from India)

Ⅰ. Resistance detected by phenotypic methods				
Antibiotic group	**Phenotypic resistance**	**Bacteria**	**Source**	**Reference**
Beta lactams	Carbenicillin,Ceftazidime, Cephalothin	Vibrio sp.	Retail shellfish samples	Sudha *et al*., 2013
	Ampicillin, Amoxycillin,	*V. parahaemolyticus*	Shrimp farm	Silvester *et al*., 2015
	Ampicillin	*V. parahaemolyticus*	Shrimp farm	Devi *et al*., 2009
	Ampicillin, Penicillin	*Listeria monocytogenes*	Fish and fishery environment	Basha *et al*., 2019
	Penicillin	*V. harveyi*	Shrimp farm	Stalin and Srinivasan., 2016
Sulphonamides	Sulphamethoxazole	*V. parahaemolyticus*	Shrimp farm	Silvester *et al*., 2015
	-	Salmonella sp.	Shrimp farm	Patel *et al*., 2020

	Trimethoprim	*S. aureus*	Fish	Saharan *et al*., 2020
Macrolide	Erythromycin	*V. parahaemolyticus*	Shrimp farm	Silvester *et al*., 2015
		Listeria monocytogenes	Fish and fishery environment	Basha *et al*., 2019
Aminoglycosides	Streptomycin, Kanamycin, Neomycin	*V. parahaemolyticus*	Shrimp farm	Devi *et al*., 2009
	Streptomycin	*E. coli and Salmonella sp.*	Fish	Saharan *et al*., 2020
Polymixins	Polymixin-B,	*V. parahaemolyticus*	Shrimp farm	Devi *et al*., 2009
Tetracyclines	Tetracycline	*Listeria monocytogenes*	Fish and fishery environment	Basha *et al*., 2019
Quinolones	Ciprofloxacin,	*V. harveyi*	Shrimp farm	Stalin and Srinivasan., 2016
Ⅱ. Resistance genotypes				
Antibiotic group	**Resistance genes**	**Bacteria**	**Source**	**Reference**
Beta lactams	*CTX-M*	*E. coli, K. pneumoniae*	Shrimp Farm	Sivaraman *et al.,* 2021
		E. coli, Staphylococcus sp.	Retail Seafood	Naik *et al*., 2017
		E. coli, K. pneumonia, Enterobacter sp.,	Retail Seafood	Singh *et al.,* 2017

		Citrobacter sp., *Salmonella enterica*		
	TEM	*K. pneumoniae*	Shrimp Farm	Sivaraman *et al.,* 2021
		Vibrio sp.	Shrimp farm and retail seafood	Silvester *et al*., 2019
		E. coli, K. pneumonia, Enterobacter sp., *Staphylococcus* sp.	Retail Seafood	Naik *et al*., 2017
		E. coli, K. pneumonia, Citrobacter sp.,	Retail Seafood	Singh *et al.,* 2017
	SHV	*K. pneumoniae*	Shrimp Farm	Sivaraman *et al.,* 2021
		E. coli, K. pneumonia, Enterobacter sp., *Citrobacter* sp., *Salmonella enterica*	Retail Seafood	Singh *et al.,* 2017
	NDM-1	Motile *Aeromonads*	Aquaculture environment	Abraham and Bardhan, 2019
Tetracycline	*tetA, tetB, tetC, tetL* and *tetG,*	*Salmonella*	Retail Seafood	Deekshit *et al.,* 2012
	tetA, tetB, tetC, tet D tetE, tetG, tetH, and *tetM*	Motile *Aeromonads*	Aquaculture environment	Abraham and Bardhan, 2019
Chloramphenicol	*catA1*	*Salmonella*	Retail Seafood	Deekshit *et al.,* 2012

	catB2, catB3, catB8 floR	Motile *Aeromonads*	Aquaculture environment	Abraham and Bardhan, 2019
Quinolones	*gyrA , parC*	Motile *Aeromonads*	Aquaculture environment	Abraham and Bardhan, 2019
Aminoglycosides	*aadA1, aadA2, aadA1a, accA4, strA-strB, aacA*			
Trimethoprim	*dfrA1/7, dfrA12, dfr13, dhfr2a, dhfr1*			
Sulphonamides	*sul1, sul2*			
Streptogramin	*VatE*			
Macrolides	*mefA, ermC, ermE, ermX, ermC*			

Microbiological Aspects of Fish and Fishery Products

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Introduction:

Fish and fish are often considered favourite foods due to their deliciousness, high protein content, unsaturated fatty acid content, and omega-3 fatty acid content. However, fish quickly spoils after being caught due to the biological and chemical components and microbial load. After twelve hours, the putrefaction process will start because of the metabolic activity of bacteria, the activity of endogenous enzymes (autolysis), and the oxidation of lipids caused by chemical reactions. After the catch, fish are particularly susceptible to spoilage, and it is essential for human health and safety that high standards of fish quality must be maintained at every stage of the food chain, from capture to consumption. Freshness and quality of fish at each step of the fish production chain can help manufacturers make safe, high-quality, and healthy fish meats, giving them an exceptional price in Global demand.

Microbial invasion:

In living conditions, when fish are first introduced to the environment, they are exposed to a wide range of microorganisms, but the fish's immune system keeps bacteria away from growing in the muscle of the fish. Once the fish dies, its immune system breaks down, letting bacteria grow out of control. During storage, they move between the muscle fibres and into the flesh. But, very few bacteria got into the meat when it was stored in ice. Since only a small number of organisms actually get into the flesh, and most microbial growth happens outside, spoilage is probably caused by bacterial enzymes getting into the meat and nutrients getting out. Still, the types of microbes usually found in fish and fish products fall into two groups: I. microorganisms responsible for spoilage, II. microorganisms that cause disease, i.e., Pathogenic bacteria

Spoilage bacteria:

In spoilage, only a subset of these contaminants can colonize and multiply in large numbers. The spoilage association in aerobically preserved fish is generally composed of Gram-negative psychrotrophic non-fermenting rods. There are several bacterial species on the surfaces of fish. According to their development temperature range, all temperate water fish bacteria are classified as either psychrotrophs or psychrophiles. Psychrotrophs (cold-tolerant) bacteria can thrive at 0°C; their growth is most efficient around 25°C. Bacteria known as psychrophiles (cold-loving) thrive best at temperatures between 15°C and 20°C. The term "spoilage association" has been coined for such a microbial community, but the precise mechanism by which one bacterial group dominates another closely related group is not always fully understood. Thus, under aerobic iced storage, the flora is virtually entirely constituted of Pseudomonas sp. and S. putrifaciens. Gram-negative, fermentative bacteria (such as Vibrionaceae) are responsible for spoiling unpreserved fish. At room temperature (25oC), the microflora is dominated by mesophilic Vibrionaceae, especially if the fish are

taken in contaminated waters. Fish spoilage is mainly caused by microbial growth, which creates flavour-altering amines, biogenic amines, organic acids, alcohols, aldehydes, and ketones.

Internal fish tissue is often considered sterile, but the bacteria on the slime layer of the skin, gills, and gut would invade after the death of the fish. Factors such as high-water activity and low acidity (pH > 6) of fish contribute to the rapid proliferation of microorganisms, which cause negative changes in the fish's appearance, texture, taste, and odour, diminishing its quality. Fish muscle consists of proteins, lipids, carbohydrates, water, and amino acid components, such as trimethylamine oxide (TMAO), urea, taurine, creatine, free amino acids, and trace glucose. In addition to psychrotrophic, aerobic, and facultative anaerobic Gram-negative bacteria, such as Pseudomonas, Moraxella, Acinetobacter, Shewanella putrifaciens, Vibrio, Flavobacterium, Photobacterium, and Aeromonas, Gram-negative bacteria also contribute to fish spoilage.

Microorganisms develop spoilage chemicals during the preservation of fresh fish. Bacterial proliferation results in the formation of a slime layer, the darkening of the gills and eyes (in whole fish), and the loss of muscle texture (softened due to proteolysis). The volatile molecules produced by protein putrefaction cause odours such as fishy (due to trimethylamine) and spoilage. Numerous proteolytic and hydrolytic enzymes are produced by Pseudomonas putrifaciens, Pseudomonas fluorescens, and other spoilage bacteria when they proliferate and multiply fast. Pseudomonas fluorescens is responsible for fish's greenish-yellow hue, whereas Micrococcus, Bacillus and Sarcina are responsible for the yellow and red hues, respectively. Yeasts and moulds are responsible for the chocolate-brown hue, and Streptomyces for the musty stench.

Table: 1 Specific spoilage Organisms in the fish and fishery products:

Storage temperature	Packaging atmosphere	Dominating microflora	Specific spoilage organisms (SSO)
0°C	Aerobic	Gram-negative psychrotrophic, non fermentative rods *(Pseudomonas spp., S putrefaciens, Moraxella Acinetobacter)*	S. *putrefaciens* *Pseudomonas*
0°C	Vacuum	Gram-negative rods psychrotrophic or with psychrophilic characte (S. *putrefaciens, Photobacterium)*	S. *putrefaciens* *P. phosphoreum*

0°C	MAP	Gram-negative fermentative rods with psychrophilic character *(Photobacterium)* Gram-negative non fermentative psychrotrophic rods (1-10% of flora *Pseudomonas, S. putrefaciens)* Gram-positive rods (LAB 2)	*P. phosphoreum*
5°C	Aerobic	Gram-negative psychrotrophic rods *(Vibrionaceae, S. putrefaciens)*	*Aeromonas spp.* *S. putrefaciens*
5°C	Vacuum	Gram-negative psychrotrophic rods *(Vibrionaceae, S. putrefaciens)*	*Aeromonas spp.* *S. putrefaciens*
5°C	MAP	Gram-negative psychrotrophic rods *(Vibrionaceae)*	*Aeromonas spp.*
20-30°C	Aerobic	Gram-negative mesophilic fermentative rods *(Vibrionaceae, Enterobacteriaceae)*	Motile *Aeromonas* spp. *(A. hydrophila)*

(Courtesy: FAO fisheries technical paper – 348)

Pathogenic bacteria:

In addition to human non-pathogenic bacteria species and the natural microflora of aquatic habitats, pathogenic bacteria are prevalent in fish. According to the European Food Safety Authority, *Campylobacter, Salmonella, Yersinia, E. coli, and Listeria monocytogenes* are responsible for significant foodborne outbreaks across the globe. However, not all bacteria are linked to outbreaks of foodborne illness caused by the eating of contaminated fish and fish products. Meanwhile, *L. monocytogenes, Vibrio spp., Salmonella, Yersinia spp., and C. botulinum* are particularly interested. These pathogens have a broad distribution in aquatic habitats and are associated with significant death rates in people due to illnesses such as listeriosis, botulism, and *V. vulnificus* infection. Thus, along with the nutritional advantages of consuming fish, there is also a possible danger to human health.

Practices to reduce the microbial load:

Physical damage, such as scale loss, bruising, and gut bursting, increases the number of sites available for bacterial attack and spread. Furthermore, cortisol levels rise during prolonged stress, affecting fillet quality. After the catch, fish may be held in the vessel for a few hours or weeks in melting ice, cooled brine, or -2 °C saltwater. Inadequate circulation of chilled brines may lead to the localized anaerobic development of specific microbes and spoiling, accompanied by the formation of off-odours. Used refrigerated brines may be polluted with many psychrotrophic spoiling bacteria, and reusing them can enhance the cross-contamination

of other fish with these microbes. Increasingly, and mainly when fish is held on board for extended durations, freezing facilities (-18 °C) may be employed to preserve the harvest (if possible). Fish may be eviscerated before marine storage, which has pros and cons. Intestinal enzymes and gut bacteria may discolour, degrade, and off-flavour un-eviscerated fish. In eviscerated fish, the incisions reveal microbial-vulnerable flesh. When eviscerating at sea, remove all stomach contents and wash the corpse before refrigerating, icing, or freezing. Whether to gut the catch at sea depends on its size.

Novel drying techniques for fish processing and preservation

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Introduction

Fish is a highly nutritious food than meat and egg and it is highly perishable because of its high moisture content which is about 80%. Fish preservation is essential immediately after the catch to increase the shelf life of fish. Preservation methods help to maintain the quality of fish for a longer period of time, prevent spoilage and decomposition, retain its original nutritional contents, and make transportation and storage of fish easier. Fish preservation techniques vary with the type, nature, size, and condition of fish. Improper handling and processing of fish lead to immediate spoilage of fish resulting in poor quality. Conventional preservation techniques such as chilling, freezing, drying, and chemical preservation are widely used for fish preservation throughout the world. Among the various preservation techniques drying of fish is the oldest preservation technique and drying means the preservation of fish by removing water from it through heating. Drying removes the moisture content up to a certain level to prevent microbial growth thereby providing greater shelf life, and reduction in weight, volume, transportation, and storage space.

Two commonly used drying methods are natural and artificial drying. Natural drying includes sun drying, and solar drying, whereas artificial drying includes a microwave, fluidized bed, spouted bed, infrared, convective drying, desiccant drying, freeze drying, osmotic, vacuum drying, pulsed electric field, high hydrostatic pressure, superheated steam drying, heat pump and spray drying *etc*. Natural drying methods are associated with disadvantages like contamination and damage by dirt, insects, rodents, birds, and animals. Sun drying of fish often results in low-quality products since drying is slow normally it takes five to seven days. Therefore, it is necessary to choose an advanced method of drying to obtain good quality products (Curran and Trim, 1985). Artificial drying methods have advantages like less drying time, good quality drying, better process control, operational safety, and higher capacity.

Infrared drying

Infrared (IR) drying can be considered to be an artificial sun drying method and it can sustain throughout the day. In recent years, infrared drying has gained popularity as an alternative drying method for foods. IR is electromagnetic radiation that is in the region of 0.78 – 1000 μm. It is transmitted and absorbed by the food surface and gets changed into heat. Generally, the far-IR region (3 – 1000μm) is used for food processing since most of the food materials are having the ability to absorb IR in this region. IR radiation impinges on the surface of the material which has to be dried and penetrated into it. Absorption of radiation increases the molecular vibration inside the material and resulted in heat generation on both the inside and surface of the material concurrently (Sakai and Hanzawa, 1994). Faster heat generation inside the material increases the movement of moisture towards the outer surface. External hot air movement over the surface of the material can remove the moisture from the surface and influence the further mass transfer from the material. IR drying provides less drying time, is highly energy efficient, uniform in drying, and has good quality dried products. Infrared offers

faster drying of products with minimum energy consumption and nutrient losses than conventional dryers. Also, IR heating provides high heat transfer with less drying time and energy cost. Drying using IR radiation will result in better quality products than another drying process since the heating is fast and uniform.

Advantages of using IR for drying include flexibility of operation, simplicity of the required equipment, fast response of heating and drying, easy installation to any drying chamber, and low capital cost (Sandu, 1986). It can be used for various food materials like grains, flour, vegetables, pasta, meat, and fish. A simple IR dryer consists of an inlet and outlet hopper, manual conveyor system, IR lamp arrangements, voltage regulator, and timer relay. Food product enters from the inlet hopper to the manual conveyor and it moves parallel to the IR lamps and dried. The IR radiation intensity can be adjusted via the voltage regulator and intermittent IR drying can be implemented by a timer relay. A pilot-scale hot air-assisted continuous infrared dryer was designed and developed by ICAR-CIFT, Cochin, India and it is presented in Fig. 1.

Description of pilot scale infrared dryer

The major components assembly of the pilot scale dryer comprised of belt conveyor, infrared radiation heating system, hot air generation and circulation, power transmission, feed hopper, discharge chute, and control panel. The drying chamber of 2.22 x 1.19 x 1.30 m was made from stainless steel sheets with 25 mm thick glass wool insulation and a folding door opening at the front. Both the outer and inner sides of the drying chamber were covered with 1 mm thick stainless steel sheet. The conveyor dryer has a four-layer conveying system with a loading area of 2 m^2 on each layer. The conveying system was composed of end rollers and conveyor belts (2 x 1 m), both were made of stainless steel (SS 304) material. The size of the dryer and loading area was selected based on the calculations obtained from the assumed dryer capacity and bulk density of the product to be dried. Stainless steel (SS 304) feed hopper (0.98 × 0.10 × 0.19 m) was designed in such a way to feed the sample throughout the width of the top layer conveyor belt as a single layer. Sample discharged from the feed hopper to the top layer conveyor belt was conveyed along and transferred first to the second layer, then to the third and at last to the fourth layer using stainless steel discharge fixed at the end of each layer. From the fourth layer, the dried sample will be discharged through the discharge chute. The drying chamber was fitted with a ceramic infrared heater of 250 W which emits radiation at a wavelength of 2.5 – 10 µm (M/s MARC, Jharkhand). A total of ninety-six IR heaters (twenty-four numbers in each layer) were fixed over each layer of the conveyor belt at a distance of 10 cm from the belt surface. The provision to cut-off IR intensity of each layer to its half load was provided using a PLC (Siemens LOGO X50) and HMI (Siemens LOGO TDI) for situations where full power is not required. Switching on and off the IR heaters of each layer was also controlled by the PLC and HMI automatically. The drying chamber has six air inlets (d = 0.20 m) and two exhaust (rectangular mesh opening) ducts for hot air circulation and to remove humid air. A temperature sensor (J-type thermocouple) was fixed inside the chamber to measure the air temperature during drying. A discharge chute was placed to collect the dried samples.

Fig. 1 Pilot-scale hot air-assisted continuous infrared dryer

The hot air generation system consists of six axial air distribution fans (Make: EAF 200 S2/AS) and six finned U-shaped electrical heaters (each 750 W). Fans were provided to pull the air from the atmosphere to circulate in the drying chamber. The fan speed was controlled using a dimmer to provide the desired air velocity. Atmospheric air entered through fans was first heated up by the electric heaters and distributed in the drying chamber. The required air temperature was obtained by regulating the temperature of electrical heaters using an auto thermal cutoff device (Make: Selec TC513). A geared motor of 0.746 kW (Make: Siemens) was coupled with the bottom layer conveyor end roller. The reversion of belt direction was achieved by chain and sprocket mechanism to operate adjacent layers in opposite directions. The conveyor belt speed was controlled by a variable frequency drive (Make: Danfoss). The setting of running and residence time of the conveyor belt was achieved with the help of a PLC (Siemens LOGO X50) and HMI (Siemens LOGO TDI). The Control panel was made separately connected with the dryer which has a display and controls for all arrangements.

Squid drying in pilot scale infrared dryer

Squids are cephalopods, which are important source of food and nutrition and suitable for human consumption (Jeyasekaran *et al*., 2010). Squids are abundantly available in ocean and consumed as live feed, fish meal and as processed seafood across countries. They are good source of minerals and vitamins and are famous in traditional cuisines. Fresh squid has short shelf life because of its high moisture content (more than 80 %) (Deng *et al*., 2011). Hence, drying can be done to preserve squid by reducing its water activity.

Fresh squid were purchased from Vypeen fish landing centre, Kochi, for the experimental trials. Squid were iced immediately, and then transferred to the pre- processing facility in an

insulated box. They were cleaned and washed using potable water and cut into squid rings of approximately equal sizes (5 mm thick ring), and then stored under chilled condition (below 5°C) prior to blanching and drying operations.

The drying of squid rings was carried out in the forced convection hot air-assisted pilot scale infrared dryer (Fig. 1). Two pre-treatments like blanching and marination were done prior to drying of squid rings. About 4 kg of squid rings were thoroughly washed in potable water and allowed to drain excess water, then it is spread over the tray as a single layer for blanching. Blanching of squid rings were done in an electrically operated steam blancher for 10 min at 100°C. Blanching causes half cooking of squid and is essential for texture improvement of squid which reduces the sticky nature of squid during drying. Marination of squid rings was done using salt, lemon juice and spice powders before drying. Marination was done for at least 30 min prior to drying. The drying operations were carried out at the infrared intensity of 3000 W/m^2 and 60°C hot air inlet temperature. The parameters observed during drying were weight loss, dryer air temperature, *etc*. at 30 min intervals. The initial moisture content, dimension, colour and texture were measured for the fresh samples. Moisture content of the samples was calculated by hot air oven method (AOAC, 1990). The weight loss of squid was measured at 30 min intervals with a digital weighing apparatus by removing it from the drying chamber for approximately 30s. The experiments were stopped once the difference between consecutive weights were 0.01 g. The dimensions were measured using digital vernier caliper. The colour in terms of L*, a*, b* values and texture were analyzed using a hunter lab colorimeter and the texture analyzer, respectively in order to check the physical quality.

The amount moisture content in the product is expressed on the basis of dry matter content of the product. It is usually expressed in percentage and calculated using the following formula.

$$Moisture\ Content\ in\ wet\ basis(\%) = \frac{Weight\ of\ water\ in\ the\ product(g)}{Weight\ of\ the\ product(g)} \quad (1)$$

$$Moisture\ Content\ in\ dry\ \ basis(\%) = \frac{Weight\ of\ water\ in\ the\ product(g)}{Weight\ of\ the\ dry\ product(g)} \quad (2)$$

$$Drying\ rate(DR) = \frac{Weight\ water\ removed\ \ from the\ product\ (kg)}{Weight\ of\ \ dry\ matter\ of\ the\ product\ (kg) \times Unit\ time\ (h)} \quad (3)$$

The drying efficiency of infrared dryer was calculated by the amount of energy required to the energy supplied to remove the moisture from the squid rings. The amount of energy required is the total of sensible heat to raise the temperature of the product to dryer temperature and latent heat of vaporization at drying temperature. (Leon et al., 2002)
Energy supplied will be the energy consumed by the ceramic heaters, energy utilized by heating coil, exhaust fans, blowers *etc*.

$$Drying\ Efficiency\ (\%) = \frac{(Energy\ required\ to\ remove\ moisture, W)}{(Energy\ supplied, W)} \times 100 \quad (4)$$

After drying the samples were analyzed for its quality in terms of shrinkage, rehydration ratio, final moisture content, colour, texture and yield.

Summary

The marinated and dried squid rings are having a huge demand in ready to heat and eat products market. It is hygienically processed and easier to cook and having long shelf life due to preservative effect of the low water activity and bioactive components from spices in the product. The pilot scale infra-red dryer can be used for continuous production of marinated and dried squid rings at the rate of 1 kg/h.

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Designing Food Safety Management System

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Introduction

The safety of food is of critical importance as food is the basic requirement for growth and sustenance of life. Food safety has become vital issue due to major credibility crisis and overwhelming public opinion about the food sector. The International Organization for Standardization (ISO) defined 'food safety' as the concept that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use (CAC, 2017). Codex, General Principles of Food Hygiene defines Food Hygiene as, "All conditions and measures necessary to ensure the safety and suitability of food at all stages of the food chain; Properly applied prerequisite programmes, including Good Hygiene Practices (GHPs), Good Agricultural Practices (GAPs) and Good Manufacturing Practices (GMPs), along with training and traceability, should provide the foundations for an effective HACCP system. Food safety is also referring to the absence of hazards entering the system at any stage of processing and causing food borne illness. Widespread food safety issues related to microbiological hazards (e.g., *Salmonella, E. coli*), contaminants (e.g., dioxins) and animal disease (e.g., BSE)results increased demand for food safety legislative. Increased consumer expectations and their concern about quality and food safety; requirement of diversified food chains; and profit-oriented food enterprises development has forced the manufactures to improve the quality and food safety standards of their products by implementing management systems. Increased demand for safe food act as pushing force on development of new, improved standards along with regulations to achieve more and more safe food. Food safety systems are focused on safety, quality, efficiency, reliability, interchangeability, and environmental friendliness along with economic factors (Wentholt et al., 2009). Through the robust implementation of various risk-based food safety management systems, food organizations are progressively mitigating and managing food safety hazards.

The Food Safety and Management Systems (FSMS) is a set of standards established to direct and control food safety aspects. It is a a set of written procedures which define the range of actions taken by the food business operator to ensure that the food produce is safe to eat, of the required quality, and legally compliant. it examines food safety management from the perspective of the entire food chain from "farm to fork." A food business organization that beholds certification for FSMS depicts assurance that the organization has taken care of appropriate Food Safety and Management System. There are public-based FSMSs by International Organization for Standardization (ISO 22000:2018), and industry-based FSMSs (Global GAP, British Retail Consortium (BRC), Safe Quality Food (SQF), International Food Standard (IFS) and Food Safety System Certification (FSSC 22000).

ISO 22000:2018

ISO 22000 is the food safety management system that can be easily applicable to any organization in the food chain. ISO 22000 was initially developed on September 1st 2005 by the ISO/TC 34/SC 17 as the first truly international FSMS standard. Food safety hazards can occur at any stage in the food chain making adequate control throughout the food chain essential. By combining PDCA and risk-based thinking to manage business risk with HACCP to identify, prevent and control food safety hazards, ISO 22000 helps organizations to reduce exposure to risk and improve safety. ISO 22000 is aligned with the requirements of ISO 9001 in order to enhance the compatibility of the two standards and to ease their joint or integrated implementation.

ISO 22000:2018 is the latest global food safety management system (FSMS). This standard replaces the old ISO 22000:2005. ISO 22000:2018 was published in 19 June 2018. The aim of the standard is to harmonize the requirements for food safety management on a global level. The ISO 22000:2018 international standard enables organizations to control food safety hazards along the food chain in order to ensure that food is safe at the time of consumption. ISO 22000:2018 applies to all organizations participating in the food chain, regardless of type, size and complexity. The standard contributes to ensure food safety throughout the whole food chain farm-to-table.

The potential benefits to an organization of implementing a FSMS are:

- ability to consistently provide safe foods and products and services that meet customer and applicable statutory and regulatory requirements;
- addressing risks associated with its objectives;
- the ability to demonstrate conformity to specified FSMS requirements.

ISO 22000 combines generally recognized key elements to ensure food safety along the food chain:

- Interactive communication
- HACCP principles
- System management
- Prerequisite programmes

Covers the principles that are common to ISO management system standards. The management principles are customer focus, leadership, engagement of people, process approach, improvement, evidence-based decision making, relationship management.

An ISO 22000 food safety management system (FSMS) can be implemented in small, medium and large-sized food organizations from all aspects of the food chain:

- Food and ingredient manufacturers
- Retailers
- Wholesalers
- Agricultural producers

- Transport, logistics and storage providers
- Packers
- Equipment and packaging manufacturers
- Caterers

Key requirements of ISO 22000: 2018

Clause 1: Scope

This clause details the scope of the international standard. This includes requirements about planning, implementation, maintaining and updating an FSMS as well as effective communications.

Clause 2: Normative references

There are no normative references within the standard.

Clause 3: Terms and definitions - 45 definitions have been elucidated for proper understanding and implementation.

Clause 4: Context of the organization

4.1 Understanding the organization and its context - determine external and internal issues that are relevant

4.2 Understanding the needs and expectations of interested parties – as per statutory, regulatory and customer requirements

4.3 Determining the scope of the food safety management system – determine scope based on product, services and processes as per external and internal issues & requirements

4.4 Food safety management system - establish, implement, maintain and continually improve the FSMS in accordance with the requirements of the standard.

Clause 5: Leadership

5.1 Leadership and commitment - Top management shall demonstrate leadership and commitment with respect to the FSMS. Ensure a food safety policy and objectives, integration of FSMS requirements with business

5.2 Policy - establish, implement and maintain a food safety policy appropriate to the purpose and context of organization which satisfy the requirements, communicate the policy

5.3 Organizational roles, responsibilities and authorities –

5.3.1 Top management shall ensure that the responsibilities and authorities for relevant roles are assigned, communicated and understood within the organization.

5.3.2 The food safety team leader shall be responsible for ensuring the FSMS is established, implemented, maintained and updated, ensure relevant training and competencies for food safety team

Clause 6: Planning

Organization plans actions to address both the risks and opportunities identified in Clause 4. It focuses on the development and use of a planning process, rather than a procedure to address both a range of factors and the risk associated with such factors.

The objectives of the FSMS shall:
a) be consistent with the food safety policy;
b) be measurable (if practicable);
c) take into account applicable food safety requirements, including statutory, regulatory and customer requirements;
d) be monitored and verified;
e) be communicated;
f) be maintained and updated as appropriate

Clause 7: Support

This clause is all about the execution of the plans and processes that will enable your organization to successfully complete their FSMS responsibilities. This is a very powerful requirement covering all management system resource needs.

Clause 8: Operation

8.1 Operational planning and control - The organization shall plan, implement, control, maintain and update the processes needed to meet requirements for the realization of safe products, and to implement the actions determined.
8.2 Prerequisite programmes (PRPs) - to facilitate the prevention and/or reduction of contaminants (including food safety hazards) in the products, product processing and work environment – appropriate to the size, type and nature of the products handled
8.3 Traceability system - uniquely identify incoming material from the suppliers and the first stage of the distribution route of the end product as per requirements
8.4 Emergency preparedness and response - ensure procedures are in place to respond to potential emergency situations or incidents
8.5 Hazard control

Clause 9: Performance evaluation

This is all about measuring and evaluating your food safety management system to ensure that it's effective and helps you to continually improve.

Clause 10: Improvement

This clause requires organizations to determine and identify opportunities for continual improvement of the management system.
Annex A: cross references between the CODEX HACCP and this document
Annex B: cross references between this document and ISO 22000:2005

Hazard Analysis and Critical Control Point (HACCP)

The HACCP system, which is science based and systematic, identifies specific hazards and measures for their control to ensure the safety of food. HACCP is a tool to assess hazards and establish control systems that focus on control measures for significant hazards along the food chain, rather than relying mainly on end-product testing. Development of a HACCP system may identify the need for changes in processing parameters, in processing steps, in manufacturing technology, in end product characteristics, in method of distribution, in the

intended use or in the GHPs applied. Any HACCP system should be capable of accommodating change, such as advances in equipment design, processing procedures or technological developments. HACCP principles can be considered throughout the food chain from primary production to final consumption, and their implementation should be guided by scientific evidence of risks to human health. Although it is not always feasible to apply HACCP at primary production, some of the principles can be applied and may be incorporated into good practices programmes (e.g. Good Agricultural Practices (GAPs), etc.

Principles of the HACCP System

The HACCP system is designed, validated and implemented in accordance with the following seven principles

1. Conduct a hazard analysis and identify control measures.
2. Determine the Critical Control Points (CCPs).
3. Establish validated critical limits.
4. Establish a system to monitor control of CCPs.
5. Establish the corrective actions to be taken when monitoring indicates a deviation from a critical limit at a CCP has occurred.
6. Validate the HACCP plan and then establish procedures for verification to confirm that the HACCP system is working as intended.
7. Establish documentation concerning all procedures and records appropriate to these principles and their application.

General Guidelines for the Application of the HACCP System

Prerequisite programmes should be well-established, fully operational and verified, where possible, in order to facilitate the successful application and implementation of the HACCP system. HACCP application will not be effective without prior implementation of prerequisite programmes including GHPs. Management awareness and commitment to food safety are necessary for implementation of an effective HACCP system. Appropriate HACCP training and competency is essential. The intent of the HACCP system is to focus control at Critical Control Points (CCPs). HACCP provides consistent and verifiable control beyond that achieved by GHPs. A HACCP approach should be customized to each food business. The HACCP system should be reviewed periodically and whenever there is a significant change that could impact the potential hazards and/or the control measures.

Private food safety standards

Private food safety standards are generally set by private firms and standard setting coalitions and aim to facility supply chain management within an increasingly globalised and competitive international food market. The main drivers for the proliferation of these private food safety schemes have been: the clear assignment of legal responsibility to food chain operators for ensuring food safety; increasingly global and complex supply chains; and, increasing consumer awareness of food and food systems and their impact on health and, in particular, on food safety.

Driving forces for the establishment of private food safety standards

- Demonstration of due diligence
- Global sourcing and the need for improved supply chain management
- Heightened consumer interest in food safety

Private Food Safety Standards in operation

BRC (British Retail Consortium)

BRC (British Retail Consortium) Global Standard was originally developed and published in 1998, the British Retail Consortium (BRC) Global Standards specify safety, quality and operational criteria for food producers and suppliers. BRC standards are accepted by many of the world's largest retail groups, manufacturers and food service organisations - providing an international mark of excellence for the certificate holder. The BRC standard has a focus on quality, food safety and legality. The BRC standard has descriptive requirements for process and hygienic control which provide clear guidelines as to how food safety should be addressed. The BRC has a simple certification process which only requires an onsite audit. For the BRC standard all NC's root cause analysis and objective evidence must be submitted within 28 days. The certificate is valid for 1 year.

FSSC 22000

The FSSC 22000 standard was developed by the Foundation for Food Safety Systems Certification (FSSC) as a response to the need of the international food sector to have an independent ISO-based food safety scheme for third party auditing and certification for their Food Safety Management System. FSSC 22000 is designed to promote international harmonization and transparency in food safety standards. The FSSC 22000 it's recognized by the Global Food Safety Initiative (GFSI). It contains a comprehensive certification program for food safety systems that incorporates the standards ISO 22000, ISO 22003, and technical specifications for sector prerequisite programs (PRPs), like ISO 22002-1 and PAS 223. The FSSC 22000 targets its focus on food safety and legal compliance. FSSC 22000 provides a good framework against which an organization can develop its food safety management system, as it is not too descriptive and has the flexibility to allow the organization to choose the best way to control its own system. The FSSC 22000 standard requires a stage 1 and 2 audit, both to be done on site. FSSC 22000 requires that critical or major NC detected in stage 1 audit have to be closed during stage 2 audit, and for minor NC the action plan should be submitted. The FSSC 22000 certificate is valid for 3 years.

Safe Quality Food (SQF)

The SQF is a food safety program that also covers product quality and process. It is recognized by the Global Food Safety Initiative (GFSI) and links primary production certification to food manufacturing, distribution and agent/broker management certification. This program comprises two codes:

SQF1000 is a Hazard Analysis Critical Control Point (HACCP), quality-based supplier assurance code designed for producers of primary food products.

SQF2000 is a rigorous and internationally-credible food safety management system for manufacturers, distributors and agents of food and beverages, and may be used by all sectors of the food industry.

IFS (International Featured Standards)

IFS comprise eight different food and non-food standards, covering the processes along the supply chain. It is developed by collaboration of 3 retail federations from Germany, France and Italy. The IFS Food Standard is a GFSI (Global Food Safety Initiative) recognized standard for auditing food manufacturers. The focus is on food safety and the quality of processes and products. It concerns food processing companies and companies that pack loose food products.

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Advanced extension techniques for translating research to development in fisheries

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Status and trends in aquaculture and fisheries

In the context of current challenges in food production, nutritional security, social transitions and growing climate uncertainties, fish and aquatic animals play important role to maintain the *status quo*. Global fish production has attained a target of 179 million tonnes in 2018 with an average annual growth of around 6 % in aquaculture and is expected to be increased to the extent of 186 million tonnes by the end of 2030. On the contrary, the trend of Indian fisheries has achieved a big leap in fish production during last seven decades witnessing a quantum leap in production i.e. from 0.75 million tonnes (1950-51) to 14.2 million tonnes (2019-20). Today, it shares about 7.7 % of the total global fish production and has established its dominance in global fisheries scenario as the 3rd largest in total fish production and 2nd in aquaculture production with an average annual growth rate of 14.8%. Out of total global production, around 87 % (156 million tonnes) accounted for human consumption covering more than 3.1 billion people in world (FAO, 2016). Mostly the developing countries account for over 60% of global fish catch, about 50% of global fishery exports in value terms and more than 60% in quantity.

In the livelihood sector, at global level about 59.6 million people are directly employed in fisheries and aquaculture at global level and more than 200 million engaged along the value chain in various upstream and downstream activities from production to distribution (FAO, 2016). In India, it provides livelihood security to more than 25 million (2018-19) of fishers and fish farmers at the primary level and almost twice along the fisheries value chain. Besides, about 84 percent of the globally engaged population in fisheries and aquaculture sector are in Asia, followed by Africa (almost 10 percent), and Latin America and the Caribbean countries (4 percent).

Despite the significant contributions of this 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 has not received adequate attention from the social scientists to understand its various socio-economic dynamics to prove the fisheries sector as a potential driver of local and national economic development.

Problems in small scale fisheries

Small-scale fisheries are normally characterized by low capital input activities, low capital investments, lack of equipment and labor-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 in case of

traditional fishing communities. They are unorganized with least social security. The informal social security system in the form of sharing of earnings among the community prevailing in the traditional fishing is hardly seen in the mechanized fishing. There are also huge regional variations in productivity among them.

Technologies are the main drivers of growth. Hence, systematic technological interventions backed by appropriate 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, cost-sharing; which can bring a change in the performance of the sector. Hence, there is an urgent need to reform that agriculture allied sectors in holistic, scientific and systematic approach to meet the recent challenges due to climate change and global competitiveness so as to achieve sustainable production and growth under different agro-climatic conditions. Keeping eye upon this, some of the advanced extension techniques have been suggested for an accelerated fishery development with focus on poverty alleviation of poor fishers.

Revamping extension systems for sustainable fisheries

The role of extension in fisheries cannot be ignored. Strong extension system is the key to bring the desired changes to meet the present day challenges related to sustainable fisheries. Basically, the end product of the fisheries extension system is to work with fisheries within an agro-climate and economic environment by providing suitable technologies to enrich knowledge and upgrade skills to improve better handling of natural fish resources and applying the cutting-edge technologies to achieve desired production level. Extension system plays a pivotal role in empowering fishers and other stakeholders to make fish farming more participatory, demand-driven, knowledge intensive and skill supportive for disseminating most appropriate technical, management and marketing skill to improve profitability in fisheries 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 ensure ecological and livelihood security. The extension system needs to disseminate a broad array of information starting from farm to fork in an integrated manner for safe delivery from field to the consumer considering 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 fishers would give emphasis on commercialization of fish and fish based products, maintenance of quality, fulfilling consumers' demands, etc., in the program planning process for the effectiveness of any extension programme.

Advanced extension techniques for technology dissemination in fisheries

With the advent of global competitiveness and market liberalization, our prevailing extension system has become defunct, which needs to be strengthened with innovative extension techniques to tackle the interwoven challenges in fisheries *viz.*, enhancing production, climate change, weather aberrations, dwindling resources, quality and safety of products, growing market demand, entrepreneurial opportunities in fisheries, conservation of environment and

international trade promotion etc.; so that fishers can adjust their production portfolio keeping eye upon the emerging trends in food consumerism in domestic as well as global markets. In India, in the course of development, many different models for transfer of technology have been tested and some robust extension approaches have been tested and validated. Furthermore, the frontline extension system of the country has been revisited and sharpened through fishers oriented approaches for technology adaptation and dissemination. As a result, the extension system in India has been designed to move beyond technology and beyond commodity through reciprocal fishers-research-extension linkages for sustainable growth and livelihood security of the farmers. In order to streamline this mechanism, a conceptual framework has to be developed in response to recognizing and considering different livelihood assets viz., *human, social, physical, natural and financial resources*. In general, fish farmers suffer from lack of access to appropriate services like credit, inputs, market, extension, technologies etc. Therefore, participatory technology development and 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, customization and diffusion. Some of the following innovative and advanced extension techniques validated through research systems must be adopted on trial basis to make fisheries more lucrative and sustainable.

a. Asset Based Community Development (ABCD) approach

Conventionally, poor people consider themselves as the impoverished population with certain needs for development that can only be resolved by various 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 fishery, 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 in fisheries through number of different fishery related 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 improving their livelihoods by developing their technical, organizational and management skills and practices (GFRAS, 2011; FAO, 2010). RAS must be designed to provide the information related to farm, organization, business management etc. recognizing the diversified actors involved in extension and fields advisory works (public, private, civil society); knowing the need of fishers, fish farmers' producer organizations (FFPOs), fishermen cooperatives and rural communities beyond technology related information and explaining them the role of facilitation and brokerage in rural development and value chains. In the case of aquaculture, large-, medium- and small-scale fishers need different types of RAS support. The large aquaculture 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). Timely sharing of research recommendations can address the problem of technology information for the fishers. In this direction, innovative extension strategies are being formulated keeping the fishers' needs and capacities in mind to pass on appropriate technologies by combining Internet, telecommunications, video, and print technologies that may bridge the information gap and empower fishers to make better production and marketing decisions (McLaren et al. 2009).

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, products, 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 FFPOs 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 FFPOs and also collaborate with FFPOs 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 fishers, 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. This can act as a platform to articulate concerns, exchange knowledge, influence policies and engage in collective action so that their livelihood remains sustainable and profitable. Effective formation of Rural Resource Centres (RRCs), Fishermen Cooperative Society, Fish Farmers' Producers Organisations (FFPOs) 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* is prioritized for suitable technological interventions in the fisheries to bring all-round development in fisheries sector in terms of *socio-economic upliftment, technological empowerment, self-governance* thereby enhancing the futuristic knowledge base and skills through *participatory framework.* MVSE emphasizes on involvement 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 fishers' farm 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 are successfully intervened in a cluster approach through participatory mode by integrating the multi-disciplinary research. The cluster of villages is adopted as model village, the success of which is later replicated to other villages. The village is 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 fishers
- Skill improvement and leadership development among the fishing community.
- Establishing linkage through pluralistic convergence of multiple stakeholders associated in the sector.
- Encouraging the market opportunities through commodity based village development (CBVD).

d. Farmers Field School (FFS) approach

The **FFS** extension approach is an alternative to the top down extension approach which was evolved as a method to solve complex field level issues in fisheries sectors. FFS aims to build fishers' capacity to analyze their production systems, identify problems, test possible solutions, and eventually encourage the participant member 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 FFS

approach is an innovative, participatory and interactive learning approach that emphasizes problem solving and discovery based learning. FFS also provides an opportunity to fishers to practice and evaluate sustainable resource use technologies, and adoption of new technologies by comparing with their conventional technologies developed in congruent with their own tradition, culture and resource use pattern. The goal of FFS approach is such that, after observing and comparing the results of field level experiments, fishers will eventually "own" and adopt improved practices by themselves sidelining the conventional ones 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 fishers can form a Farm School under the guidance of a FFS facilitator. Extension workers, NGO workers, fishermen co-op members or previously trained fishers can become Farmer Field School (FFS) facilitators. The facilitators are trained by master trainers, who have expertise in the particular subject matter. FFS is a time bound activity usually covering one production cycle or a year.

It is also significant to note that irrespective of the merits of the technology, the acceptance to technologies is influenced by the extension methods. Farmer Field School (FFS) model has been accepted as a good extension technique because of its exclusively participatory nature. FFS was also found to be effective in avoiding barriers like socio- economic constraints, infrastructure problem and incompatibility of technology for the adoption of sustainable fishery practices.

The basic component of FFS is setting up of a Participatory Comparative Experiment (PCE), commonly referred to as Participatory Technology Development (PTD), whereby the fishers 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.
- Fishermen are decision makers.

e. Market Led Extension (MLE) approach

In order to make farming more enterprising, extension professionals need to be pro-active beyond the regular objective of maximizing the productivity of the fishers by transferring improved technologies rather fishers should be sensitized on various aspects of farming like culture, harvest, quality, processing and value addition, consumer's preference and market intelligence. This will help the fishing 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 (DFI). With the globalization of agriculture, emphasis on productivity and profitability to the farm enterprises has been 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, fishers are viewed as 'Fish-entrepreneurs' who expects high returns 'Rupee to Rupee' from his produce by adopting a diverse basket 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 fishers to get better price. 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 agro-enterprises. 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 fishing 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 fishery extension system through introduction of Information and Communication Technologies (ICTs). The ICT-enabled extension system referred to as Digital Extension has the potential for enabling the empowerment of fishing communities by improving their access to information and sharing knowledge with innovative e-agriculture initiatives (Saravanan, 2010a).

With the phenomenal growth in information and communication technology, use of ICT application in agriculture and allied sectors 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. 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, CIFTFISHPRO, CIFT Lab Test, CIFTraining 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 holistic agricultural development.

g. Disruptive Extension:

Recently, a new extension technique 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 with a pre-conceived idea about the field level problems. It is an entrepreneurial oriented sustainable extension system that can be able to transform every link in the food chain, from farm to fork, pond to plate and deck to door. It is a combination of different innovative extension techniques like ABCD, CRE (cost-recovery extension), MVSE, CBVD etc. blended with suitable conventional approaches, 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.

Fisheries embraces diverse actors in its endeavour to support their livelihood system giving an impact in food and nutritional security. At the same time, the contribution of women fishers 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 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 advanced techniques of extension should be based on capacity building, skill development, people's participation along with government initiative to provide policy support in line with the cutting-edge technologies. Much effort has been initiated in going beyond the farm and the fishers and focus on beyond the technology to a wider innovation system.

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Micro enterprises in fisheries for livelihood security- scope &challenges

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While talking about entrepreneurship, I remember the quote "Only the paranoid survive." ***By Andy Grove, former CEO of Intel.***

Entrepreneurship, according to Onuoha (2007), "is the practice of starting new organizations or revitalizing mature organizations, particularly new businesses generally in response to identified opportunities." Schumpeter (1965) defined "entrepreneurs as individuals who exploit market opportunity through technical and/or organizational innovation". But the most popular definition being "entrepreneurship is about taking risk" by Frank H. Knight (1921) and Peter Drucker (1970).

What is the risk in entrepreneurship?

In one word it is Money..its all about losing money and the bitter consequences of it at individual, family and societal level, and at a broader sense at national level. But still entrepreneurship is the most widely discussed and topic catching attention of economists world over, because of its potential for economic growth, job creation, and regional and national competiveness.

Is there something called Entrepreneurial behaviour?

Entrepreneurial behaviour has been defined as the study of human behavior involved in identifying and exploiting opportunities through creating and developing new ventures (Bird & Schjoedt, 2009). Entrepreneurial behavior is also increasingly recognized as a proponent to social change and facilitating innovation within established organizations (Kuratko, Ireland, Covin, & Hornsby, 2005). There is a belief that it's the entrepreneurial behaviour of people in a Country which decide the initiation and growth or sustainability of entrepreneurship there.

A Special Issue on Entrepreneurial Behavior emphasizes the importance of refocusing research attention towards concrete and observable human action in venture and organizational creation and emergence (Bird, Schjoedt, & Baum, 2012).

Although entrepreneurs in different countries usually share some universal traits, they may also have other traits that are specific to their own culture. For example, entrepreneurial activity is encouraged as an avenue to stimulating economic growth and empowering marginalized segments of population in less-developed countries (Yasin, 1996).

Why to think of enterprises in food processing sector?- The case of India

According to Ministry of Food Processing:

- The **Indian** gourmet **food market** is currently valued at US$ 1.3 billion and is growing at a Compound Annual Growth Rate (CAGR) of 20 per cent. **India's** organic **food market** is

expected to increase by three times by 2020. The online **food** ordering business in **India** is in its nascent stage, but witnessing exponential growth.

- Its 350 million strong urban middle class with its changing food habits poses a huge market for agricultural products and processed food.
- Food processing industry will show the annual growth of 40-60% in next five years

Need for Value addition

- Value addition of food products is expected to increase from **8 per cent to 35 per cent by 2025**
- **86% of households** prefer to have instant food due to steep rise in dual income level and standard of living, convenience, and influence of western countries.
- The Food & Grocery market in India is the sixth largest in the world. Food & Grocery retail market in India further constitutes almost 65% of the total retail market in India.
- By 2020, Indian Food and Retail market is expected to touch $ 828.92 bn
- Consumer spending rate on processed food had increased **7.6% (2008 to 2010)**

World over, the entrepreneurship development, especially based on value addition, is paid huge attention. The Global Entrepreneurship Development Index(GEDI) methodology collects data on the entrepreneurial attitudes, abilities and aspirations of the local population and then weights these against the prevailing social and economic 'infrastructure' – this includes aspects such as broadband connectivity and the transport links to external markets. The share contribution form a sector to the **State Value Added (GVA) is also taken as an important indicator rather than Gross Domestic Prodect(GDP). Gross Value Added(GVA)** measures the value added to the goods and service i.e it quantifies the productivity of the economy

Value addition of fish for entrepreneurship

Fisheries being an important sector contributing to the country by way of providing quality protein to the people there, employment, and export earning, the revenue generation from value addition of fish is also important.

Fish is the source of best source of animal protein and any food out of fish is now considered a health food. This indicates the scope of value addition of fish and staring enterprises based on that. This will become again attractive, when the opportunities are made accessible for the primary producers, the original custodians of the resource.

But a highly perishable commodity, fish require scientific approach for the value addition and building its value chain extending to ultimate consumer. The resource, the technology, the final product, the packaging , pricing etc , in nutshell the business model, should be decided according to the market opportunity and identifying the market demand.

The products range various processed ready to cook and ready to eat products to live fish. But in any entrepreneurship development process, the enterprenuer has to go through different

stages which may vary according to the innovation, type of market, skill levels, state support, legal parameters and of course the entrepreneurial potential of the person or the group.

Accoding to Barraza Carols, Entrepreneurship has four stages

- **Innovation**

  Generating the idea, innovation, identifying a market opportunity, information search, conception, screening ideas for feasibility, identifying where to extract value and the development of the product or service.
- **Triggering event,**

  This stage involves gestation, the motivation to start a business, the decision to proceed, the business planning, identifying the different resources required, risk assessment, resource acquisition and assembling.
- **Implementation**

  This stage includes infancy, incorporation, setting up and launching the new venture, business strategy, implementing the business plan, running the business, deploying of resources, building success and managing the venture.
- **Growth**

  This phase is stage of adolescence, maximizing profits, harvesting the rewards and continually growing the venture to include other opportunities

Accordingly, in the fish based enterprises also, one should understand the fish value chains existing in the locality, both in inland as well as marine sectors and identify the right opportunity. The screening of market opportunity as well as identification of suitable innovation is of equal significance. The length and the type of processes involved in the fish value chain vary based on the markets involved. The vulnerabilities also should be kept in view.

Fish based Micro- enterprises from ICAR-CIFT

ICAR-CIFT has developed and standardised different business models, giving a special focus on women, for staring micro-enterprises in fish. Some are based on fresh fis and some based on dry fish and yet another range of products based on secondary raw materials. From edible products like pickles, wafers, battered and breaded products, dry fish to organic manure from processing waste is covered under that. The Institute has proven the viability of such models in coastal villages through pilot level demonstration units. Through series of field level programmes, knowledge and skill development is achieved among fisherfolk. Thy eenterprise development is promoted in P-P-P mode.

Micro enterprises & Small business

While discussing about the scope of **micro enterprises** in fisheries, one should surely know what is the difference between a micro enterprise and a **small business.**

Micro-enterprise is a business employing fewer than 10 people, and with an annual turnover or a total balance sheet which does not surpass 2 millions Euros. Micro-enterprises belong to the Small and medium enterprises category

Micro-enterprise usually employs upto 10 employees only, while small business may go upto a scale of 500 employees

Scope

Technological developments in fish processing sector offer scope for innovation, increase in productivity, increase in shelf life, improve food safety and reduce waste during processing operations (Ninan,G).

Challenges

The undulations in availability of resource as well as the price is the major challenge. Constant price fluctuation, perishability of the products, poor information literacy of costal women etc also pose threat is enterprise development as well as in its sutainability.

One has to be a dreamer, a thinker and at the same time a street smart to become an entrepreneur. The opportunities are immense, but challenges also plenty. Hence, as Jessica Herrin, founder and CEO of Stella & Dot told, "You have to see failure as the beginning and the middle, but never entertain it as an end." -

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Value Chain of Fish and Fishery Products: Global Status, Issues and Opportunities

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Introduction

The concept of value chain has attracted the attention of academician and management professionals, such that its usage has transcended from the level of a marketing management tool to that of a policy analysis one. A value chain describes the full range of activities which are required to bring a product or a service from conception, through the different phases of production and delivery to final consumers (Porter, 1980). Often the concept of value chain is interchangeably used to notate a market chain, but there are very critical differences between them. While the market chain analysis intends to provide information on profitability for various agents along the market chain (Ferris *et al*., 2001), a value chain analysis describes the range of activities required to bring a product to the final consumer and, the extent to which intermediaries/agents gain from participating in the chain (Jacinto, 2004). In that context, a value chain describes the distribution of the benefits or value addition to different economic agents, and touches the realms of development economics. In the initial days of the development of the concept, it was used for analyzing a single company, a sector, an organization or a product; however, later it was developed to analyze single or multiple sectors and to develop policies.

Kaplinsky and Morris (2000) identify three sets of reasons for the importance of value chain analysis. With the globalisation of labour and capital, and emergence of division of labour, achieving efficiency of production has gained greater policy focus. The corporate world try to attain systematic competitiveness in the context of growing division of labour and global dispersion of production components so as to achieve efficiency in production to penetrate global markets. Value chain analysis is also done to understand the dynamic factors that plays, so as to make the best out of globalisation. This approach essentially focuses on markets, with the aim of achieving overall efficiency in terms of increasing productivity and reducing cost. However, the attainment of efficiency need to factor in the opportunity cost of the resources and optimise the benefits over a long period of time. The trade-off between efficiency attainment and equity in distribution of the benefits for the stakeholders has also attained significance. Development of a win-win situation calls for imparting efficiency in attaining targets while generating maximum benefits to the actors along the value chain. In that context, sustainability of the value chain emerges as an important consideration.

1.Porter's value chain concept

The concept of value chain has its origins from the commodity chain approach, which focused on the physical product flow from the producer to final consumer. Michael Porter (1985) put forwarded value chain as the value addition in competitive markets. It is the core element in the production-to-consumption chain of activities, within an organisation framework. The value added should be more than the marginal cost of that activity, for the particular intervention to be sustainable. However, the concept doesn't address the larger concern of economic development of the sector, but was limiting itself to the organisational management. Porter's VC concept in that way deals essentially with firm-level strategy and not with broader economic development.

In Porter's concept ,the activities of the firm can be broadly split into 'primary activities' and 'support activities', depending on the whole functioning (Figure 1). The primary activities include inbound logistics, which include sourcing of the raw material; operations which include conversion of the raw material into final products; outbound logistics which include system of distribution centres, wholesalers, retailers and consumers; services including trainings. The primary activities, either alone or in combination of them are essential for the firm to develop the competitive advantage for the value chain to be economically successful. On the otherhand, the support activities assist the primary activities in helping the organisation achieve its competitive advantage. They involve procurement including quality management; technology development to obtain competitive advantage with in the organisation including development of online facility; human resource management which includes recruitment, trainings, motivation, competitive advantage etc.; and, managing firm infrastructure, including managing finances, legal structure, and management structure. A co-ordination of all the activities are necessary for successful value chain development.

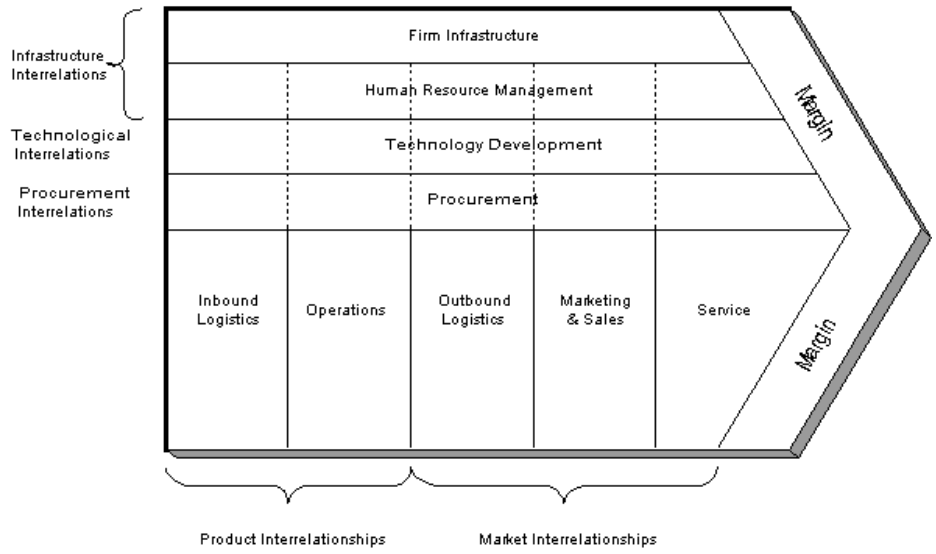


Figure 1: Michael Porter's value chain concept

2.Global Commodity Value Chain

On the otherhand, the global commodity value chain (GCV), as introduced by Gereffi and Korzeniewicz (1994), provides a developmental dimension, by introducing chain governance. The element of chain governance envisages how various firms across the entire chain are coordinated (or strategically linked) in order to be more competitive and add more value. Under this framework, the value chains are derived by the nature of demand from the final consumers and the process of globalisation.

The concept of global commodity value chain (GVC) shifts the focus of the analytical framework to demand side factors, compared to the supply side factors that are seen in case of Porter's value chain concept (Gereffi, 1994; Kaplinsky, 2000). This shift in the orientation of the value chain has been a result of the substantial influence that the global retailers wield over the food systems of the developing countries. The control is more forceful in those food commodities that undergo relatively low level of processing and therefore flexible. As the demand consideration varies across markets of different countries, primarily on account of different quality standards emphasised, the producing nation needs to take into account the cost of compliance. For example, the quality criteria prescribed by export markets like US is considerably different from that of Europe. This creates redefinition of markets according to quality criteria, and leads to an association which mutually reinforces quality and demand driven value chains. In such circumstances, the capability of the supplier to adhere to the quality prescriptions ceases to be a major consideration for the hegemonic retailers, and the sunk cost turns irrelevant. One prime contribution of the global commodity value chain is the recognition of globalisation as a powerful economic phenomenon in determining food system performance and retailer hegemony as a prime factor that affect the value chain.

3.Global fisheries value chain

Perhaps, fish happens to be one of the few commodities that have witnessed globalisation through trade. The globalisation of fish value chain involves participation of multiples countries and partners, as fish harvested/ produced in one country is processed and exported though other countries to the consumers located in remotely located places. Globally fish production has increased steadily over a period of time (Table 1). With the growth in per capita income and changes in taste and preferences of the consumers towards marine products, the demand for fish has also increased. Consequently, the trade in fish has increased steadily over a period of time. The research and developments in fishing, aquaculture, fish processing and value addition, packaging, quality assurance and financing has served the purpose of catalysts in global fish value chain.

One critical step that resulted in fish value chain is globalisation in fish trade, particularly through World Trade Organisation, where the developing countries in general could gain significantly by upgrading the value chain. Ensuring fish quality and safety by following the stringent sanitary and phyto-sanitary conditions was the most significant technical upgradation that helped out. The globalisation has opened up new areas to realise value by

upgrading diversifying the value chain in terms of 4 “p”s, namely product, place, price and promotions as is usually seen in case of supply chain management literature.

Table 1: World Fisheries Aquaculture Production, Utilisation and Trade

	1986–1995	1996–2005	2006–2015	2016	2017	2018
	Average per year					
	(million tonnes, live weight)					
Production						
Capture						
Inland	6.4	8.3	10.6	11.4	11.9	12.0
Marine	80.5	83.0	79.3	78.3	81.2	84.4
Total capture	**86.9**	**91.4**	**89.8**	**89.6**	**93.1**	**96.4**
Aquaculture						
Inland	8.6	19.8	36.8	48.0	49.6	51.3
Marine	6.3	14.4	22.8	28.5	30.0	30.8
Total aquaculture	**14.9**	**34.2**	**59.7**	**76.5**	**79.5**	**82.1**
Total world fisheries and aquaculture	**101.8**	**125.6**	**149.5**	**166.1**	**172.7**	**178.5**
Utilization[2]						
Human consumption	71.8	98.5	129.2	148.2	152.9	156.4
Non-food uses	29.9	27.1	20.3	17.9	19.7	22.2
Population (*billions*)[3]	5.4	6.2	7.0	7.5	7.5	7.6
Per capita apparent consumption (*kg*)	13.4	15.9	18.4	19.9	20.3	20.5
Trade						
Fish exports – in quantity	34.9	46.7	56.7	59.5	64.9	67.1
Share of exports in total production	*34.3%*	*37.2%*	*37.9%*	*35.8%*	*37.6%*	*37.6%*
Fish exports – in value (*USD billions*)	37.0	59.6	117.1	142.6	156.0	164.1

[1] Excludes aquatic mammals, crocodiles, alligators and caimans, seaweeds and other aquatic plants. Totals may not match due to rounding.
[2] Utilization data for 2014–2018 are provisional estimates.
[3] Source of population figures: UN DESA, 2019.

Source: Adapted from FAO (2020)

However, globally greater focus is being accorded to sustainable value chain while bringing about an upgradation in the entire value chain process and elements. This particularly so in the context of unsustainability issues in global fish production in terms of over-exploitation of resources in the capture fisheries, mainly marine fisheries. This has the potential to affect the life and livelihood of millions of people and in term of poverty, labour usage and food and nutritional security.

Who gains from the global fisheries value chain development

Who gains and who losses in the value chain development is one among the key questions confronting the fishery value chain development. The major concerns is that what is the share of additional benefits that has accrued in the value chain development that is passed on to the producers. Also, of significance is how the value chain development translates in to sutainable outcomes in terms of fish resources. Addressing this questions needs a proper analysis of the value chain, delving deep into the major actors, activities and the flow of economic benefits along the value chain. Value chain analysis forms the stating point in an effort to upgrade the value chain and harness benefits out of the value chain development.

Value chain analysis

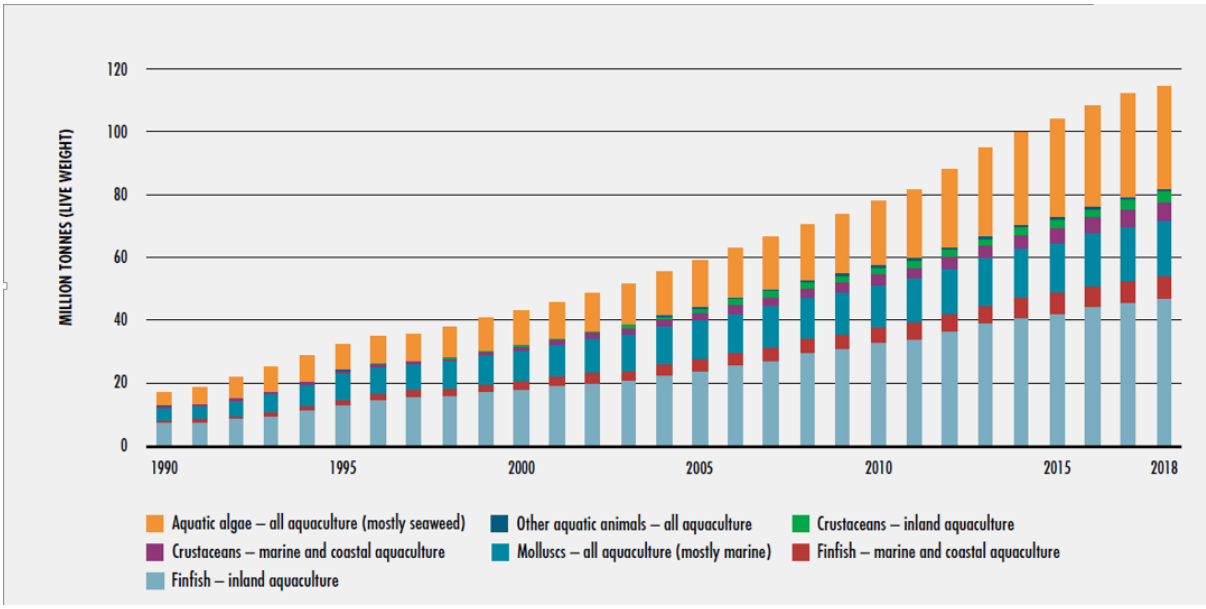
A Value Chain analysis assesses whether the value chain is effective at maximising the opportunities for adding value in the eyes of the consumer; and efficient in adding value, producing, processing and distributing at the least cost (CRFM, 2014). Value is getting added at every step or node in the value chain. The major constraints faced in the value chain development at every stage is subjected to the approach. The concept when applied to fisheries and aquaculture simply refers to all the activities and services —from input supply to production (capture fisheries and aquaculture farming), processing, imports, wholesale and finally, retail. In reality, the total value chain takes into account the input suppliers, support services providers including regulatory, financial, technology transfer and all the other actors who comprise the enabling business environment in which the industry operates. In the concept of value chain, the starting point of analysis is the consumer, rather than the producer as is usually done is a supply chain analysis. The value chain changes as the consumer turns more aware and conscious about issues of concern including environmental pollution, quality and safety concerns. The value chain changes with globalization and changes in the taste and preferences of the consumers.

For fishers, managers of organisations involving in fisheries, and policy makers, the value chain approach provides a useful and practical tool for assessing the development status of the fisheries and aquaculture sector. and in analysing the opportunities and constraints for its future development. The process of Value Chain analysis is done in accordance with a number of sequential steps as: mapping the value chain, selecting and prioritizing value chains; analysing the value chain, formulating and upgrading strategies for value enhancing in the, implementing the upgrading strategy; and monitoring and impact assessment.

4.Issues and prospects in global fisheries value chain: A snapshot

Fish and fish products has a critical role in meeting food and nutritional security, reduce poverty and help in leading a healthy and active life. In that sense, the fisheries economy contributes to the Sustainable Development Goals (SDGs) as envisioned by the United Nations. The demand for fish is more elastic, and therefore with an increase in per capita disposable income, the aggregate demand would be rising. The increased demand is to be met by domestic production and/or import.

The fish production is driven mainly by aquaculture. The marine capture fisheries is stagnating in most part of the world. Forecasts suggest that it would continue be so in the medium term (FAO, 2020). The aquaculture would be dominated by Asian countries, especially China. Further, aquaculture is also witnessing a qualitative change in terms of diversification- towards production of see weeds (algae) (Figure 1). These changes are sufficient enough to alter the value chain, by providing new challenges and opportunities. The increasing dominance of aquaculture in the fish production implies greater influence on fish prices by price swings of farmed fish and the variability in the supply chain of inputs and services for farm fish.



Source: Adapted from FAO (2020)

The fish trade, on the otherhand, is highly developed in terms of product diversification and value chain complexities. However, the participation to the high end value chain is limited for small scale fish producers. Therefore, much of the fish consumption is in fresh form without undergoing value addition of high order. The global south gains through fish trade in terms of revenue gains, but there are concerns on the trade-off between domestic nutritional security and revenue out of fish trade. This points to the need to shift towards advanced value addition system. The utilisation as prepared or processed fish products are on gradual increase (Figure 2). It would create opportunities for income and employment generation.

The changes in the trade system is poised to alter the value chain. The strict sanitary and phytosanitary conditions that characterise the international requirement for fish trade warrants investment by the global south in establishing technologies and institutions for ensuring safety and quality compliance in accordance with acceptable global standards. Further, the development in ICTs in terms of online delivery inputs, services and outputs (fish) has brought a paradigm shift in the way the fisheries value chains are organised. The development in ICTs in terms of advisories, extension systems, quality management, traceability and automation are forces sufficient to challenge the existing value chain and effect a qualitative change. An exhaustive, but not an exclusive list of forces that could challenge the value chain in fisheries is provided below:

Drivers of changes in value chain and some examples

	Dimensions/ factors	Remarks
I	**Demographic changes**	
a	Ethnicity and race	Example: Preference to meat over fish in some societies Generally, Countries in East has high demand for variety of fish Some commodities have demand in certain regions - Eg. Sea cucumber and shark fins are luxury for some Chinese markets
b	Geographic distribution	Eg. Fish harvest and post-harvest depends on the availability of fish species. Tropical regions are dominated with multi-species fishery. Culinary style varies depends on regions and fish species commonly available.
c	Extent of travel	Eg. Global village lead to change the traditional habits. Wide travels expands the horizons of demand, and the market needs new products.
d	Literacy	Literacy and awareness has impacts on demand for food safety, quality, sustainability of fishing practices, adoption of responsible fishery, climate change, and pollution.
e	Retailer promotion	The important variables could be retailer competition, promotion, kind of social networks.
II	**Consumer preferences**	
a	Price	Critical element of product demand.
b	Quality	Maintaining quality add extra cost, countries all over the world upgrade and revise the quality standards. Examples are: EU directives food safety and sanitation, USA- USFDA, Japan- Food and Sanitation Law.
c	Convenience	Generally high demand for clean, cut and ready to cook or ready to eat forms of fish and consumers are willing to pay extra premiums.
d	Year-round availability	Aquaculture makes fish available year round compared with capture fisheries, and this affects the value chain planning and operations. Processing help to overcome seasonality, and wastage.
e	Variety and nutritional content	Nutrition is the major attribute considered in purchasing decisions. For example, fish is rich in Omega 3 fatty acid having several health benefits.

f	Safety	Food safety is emerging as a major attribute with regulations on quality parameters. Strict quality and safety guidelines are in voge in several countries- EU, Japan and the United States have strict regulations. Further, the developing countries follows the suit, in domestic markets also
g	Greenness	Sustainability is the main concern of the green or environmental friendliness, and extra for the conservation measures, eco-lables, organics, WTP
h	Fairtrade	Fair trade label attracts premium prices
III	**Buyer specification**	
a	Volume	The volume varies with the type / class of buyers, for example, individual buyer and institutional buyers. Variables like seasonality, economic status, cultural aspects and purchasing power of the consumers affects the trade volume
b	Presentation	Presentation style appeals and attracts consumers. Good packaging materials gains importance in this context. Clean cut ready to cook or eat fishery products attracts more consumers
c	Labelling	Intended to provide information on product composition and safety. EU adopted Traceability for all fisheries and aquaculture products.
c	Certification	Certification and labelling of certified products aim to identify products that follow certain minimum standards or regulations, such as standards for quality, organic production, fair trade, or sustainability
IV	**Technology**	
a	Marketing information systems (MIS)	Developments in MIS provide information required for value chain adjustments. Developments in mobile telephony and spreading of internet facilitate this. Traders and non-governmental Organizations (NGOs) are also contribute for information flow.
b	Category management methods	The fish products and supplies category are extremely diverse.
c	Progress in supply chain management	Involves a large number of stakeholders between the fisherman/fish farmer and the final consumer. There are several possible routes (harvesting and processing sector) in fish value addition in terms of geography and actors. Importing fish to a second

		country, value addition in that country and re-export is also emerging a value chain.
d	Harvest and processing technology	Development of new products which are ready to eat (RTE) and ready to serve (RTS) have promoted newer value chain. Further, ethnic fish preparations are gaining currency. Harvest technologies in accordance with sustainability concerns. For example, non-polluting and energy efficient fish harvesting vessels, usage of turtle excluder devices etc.
d	Transport and handling advances	Advances in transport facilities has facilitated emergence of live fish transportation and emergence newer value chain.
V	**Regulatory change**	
a	Official standards and associated certification	Standards and certifications aim to protect consumers, environment, sustainable resource utilization, fishers and trade relations, and led to emergence of several agencies who undertake these operations.
b	Labelling (nutrition, country of origin labelling, allergens)	Labels on nutrition, country of origin, allergens. Regulatory systems have responded with new product and production standards, approval processes, risk-assessment processes and labelling requirements.
c	Environmental protection	Laws on environmental protection has emerged at international level (Eg UN). The examples are: United Nations Convention on the Law of the Sea (UNCLOS) to promote sustainable fishing. Code of Conduct for Responsible Fisheries (1995) in a non-binding commitment on the part of all signatory states to adhere fishing practices that promote responsible fishing.
d	Labour and animal rights	Targeted for minimal harm to or exploitation of humans, animals and/or the natural environment. For example, ethical consumerism is gaining currency and is changing the value chain. ILO - with fundamental workers' rights
VI	**Other factors**	
a	Market access	Quarantine requirements and non-tariff trade barriers restrict the fish trade, but provide opportunities for value chain development that facilitate addressing these concerns. Value-added fish and fishery products require

		substantial investment. However, compliance with the guidelines, like HACCP has occurred in several processing units of developing countries, and have given rise to development of newer value chain activities.
b	Distribution and retailing	Major changes in distribution and retailing are eenrgy, transport and labour. Poor infrastructure, logistics and weak policy hinders the success of the fish industry.
c	Economic growth trends	The major factors that affect the demand for fish products are per capita disposable income, availability of alternate nutrient sources, urbanisation, and population growth. Further development of online delivery mechanism, financing and distribution of wealth are key factors.

Source: Compiled from De Silva (2011), with inputs by the author

Some of the factors that provide challenges and provide newer opportunities for value chain development are provided in the above table. In recent times, sustainable food value chains have emerged currency all over the world. However, it requires substantial investment, from both public and private sector, to develop capital sufficient enough to harness the productivity (Suresh and Parappurathu, 2018).

5.Sustainable food value chain

While the development economics has been focusing more towards the sustainability issues, value chain development literature has not addressed the issue of sustainability as the bottom line of developmental thinking (FAO, 2014). Of particular importance is how the value chain analysis addresses the issues of environment, economics and society at large. The sustainable food value chain (SFVC) concept, as used by FAO, visualises an element of sustainability and applies it to specific nature of food production, value addition and distribution. However, many services used in a single commodity approach are common to many agricultural products- for example, marketing, financing, information etc are used by many commodities, and therefore a more holistic approach would gain currency in the times to come. However, for analytical purpose, the concept of SFVC has to look into commodity chains, so as to delineate the broader trends, identify intervention points and estimate the impacts. The concept of SFVC is relatively newer one, and is largely developed by FAO. Consequently, this session largely relies on the concepts as provided by FAO (2014).

Interaction of economic, social and environmental elements

The sustainability of the value chain is determined by the economic, social and environmental elements. A value chain is considered economically sustainable if the required activities at the level are economically viable and or profitable. However, the outcome of the economic activity needs to be socially and culturally acceptable to characterise it to be socially

sustainable. The environmental sustainability is attained largely if the value chain activities doesn't impact the environment adversely and maintains a non-declining natural capital stock.

Principles of sustainable food value chains

Though each food value chain is unique, the sustainable food value chain is characterised by 10 interrelated principles, as noted below:

a. Economically sustainable: Commercial viability, competitiveness, growth etc. The upgraded VC should provide higher profits, income etc.
b. Socially sustainable: Inclusiveness, equitability, social norms, social institutions and organizations. Generation of greater share of value (profit and wage income) to the poor, broad-based, and equitable distribution along the VC, with no adverse effect on the poor.
c. Environmentally sustainable: Non-declining natural capital stock, for inter-and intra-generational equity. Minimise environmental footprint (water footprint, carbon footprint etc) is an issue.
d. Dynamic and system based: VC is dynamic due to changes in market demand, technology, available services, profitability, risk, barriers to entry, large-firm behaviour, input supply and policy etc. VC needs to be adapt to changes. Sub-systems are linked, and identifying root cause in the system is the solution to improve.
e. Governance centred: Needs to analyse how value chain actors of different typology transact vertically and how they collaborate horizontally. The governance needs to bring in win–win solutions, and impart element of trust among the value chain actors.
f. End-market driven: The value is ultimately determined in the end-market when consumers purchase the product/service; and therefore consumer analysis needs to be the starting point for the VC improvement.
g. Vision/strategy driven: to be successful, the actors have to carefully target development goals and stakeholders. The strategies need to revolve around a vision which is realistic, quantifiable (as far as possible) and targeting (as far as possible) selected stakeholders. The improvement of VC should focus on that area where largest impact is possible.
h. Upgrading focused: It requires carefully assessed and innovative upgrading activities to translate a vision and strategy into an effective plan. The upgradation can be in the form of technology, organisation, institution, network etc.
i. Scalable: The VC upgrade allows replication process that is based on realisitic assumptions.
j. Multilateral: It requires that the driver of the process of VC upgradation is private sector as driver and the other agencies (public sector and civil society organisations) as facilitators

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Why Gender Matters for Sustainable Fisheries and Aquaculture

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Introduction

Gender is a very important developmental issue and this is reflected in the inclusion of with Gender Equality as a key SDG (SDG5- Gender equality, with a goal to achieve gender equality and empower all women and girls) (https://sdgs.un.org/). The targets address several facets of inequality that women face in communities and societies around the world, including systemic ones that need interventions to ensure that the core principle of gender equality is achieved. While examining the progress in achieving the targets, it can be observed that while there have been positive changes, the progress on structural issues at the root of gender inequality is insufficient. And it is often these structural issues that continue to perpetuate gender inequalities. There are various forms of societal, legal, political and economic discrimination that continue to disadvantage women. Policies that address larger developmental needs like poverty and unemployment often tend to be gender neutral or rather gender-blind, while in fact needs, impacts and potential solutions may all be gender specific. Added to this, global shocks, either natural or man-made, exacerbate inequalities further as the recent COVID-19 pandemic has shown (World Economic Forum[1], 2021). Strategies to combat disruptions and shocks, just like policies, also are generally gender neutral, leading to further disadvantaging women. Gender equality is also a guiding principle in the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries (FAO, 2005).

Though several decades of research and advocacy have gone into bringing these issues to the forefront, there is still the need for greater understanding, recognition and action. Overall, India ranks 140 among 156 countries in the Global Gender Gap Index 2021. Further in the sub-indices, India is ranked 151 in the Economic Participation and Opportunity, 114 in Educational Attainment, 155 in Health and Survival, and a positive indicator in Political empowerment where it is ranked 51. The report further observes that economic opportunities for women are extremely limited in India (22.3%) and the gender gaps tend to widen together with seniority levels (World Economic Forum[2], 2021). Some of the data could also be missed as there is no mechanism to count women's work, like in fisheries and aquaculture sectors. Data point out that in India about 50% of adult population in marine fishing communities are women and about 30% are employed in the sector. This is probably underreporting or a reflection of the data-insufficiency, as the same data set indicates that about 60% of wild seed collectors and 70% of allied workers are women. The allied sector is diverse and has several types of activities all of which are crucial inputs to the functioning of the fish value chains like net making and mending, traditional processing, marketing and commercial seafood processing etc. Globally, 50% of the 120 million in capture fisheries are women and out of 59.5 million people in the primary sector in fisheries and aquaculture, 14% in marine and 20% in inland sectors are women (close to 15 million women). Also about 90% of processing workers and 60% of fish vendors are women. In inland fisheries catch estimates the

underreporting is by about 70%, which was highlighted in the Illuminating hidden harvests work (Harper et. al., 2022).

Women in fisheries and aquaculture – data invisibility and policy blindness

Fisheries and aquaculture are food production systems where women's activities are vital in India, just as in several other parts of the world. There has been an increase in academic and advocacy work in the recent past on gender in aquaculture and fisheries. There are studies being undertaken, associations being formed in various parts of the world taking up advocacy on gender issues in the sector and gendered impacts being included in most programme implementation. Yet, women continue to invisible, increasingly marginalised and are facing the associated challenges that come with this exclusion and marginalisation. In small scale fisheries about one on four workers are women. Their fish work makes important contributions to food, nutritional and income security of households. Considering that women in the fisheries and aquacultures sector would probably form one of the lowest rungs of labour force they face greater inequalities and their contributions continue to be invisible. The poor recording of sex-disaggregated data has been a recurring issue, and is one of the key areas needing strengthening, not just in India but globally (GAFS, 2018). Data is fundamental for zeroing in on the issues and for supporting policies and guiding programmes. Fisheries and aquaculture related policies are generally aimed at increasing fish production and schemes and programmes are tailored to achieve that goal. Mechanisation/modernization, commercial aquaculture, mariculture and other capital intensive programmes are implemented for this. Both public and considerable private investments fuel this growth. These policies, programmes and schemes do not look at gendered impacts. And when women are not specifically integrated or thought about in these programmes, there is exclusion, which may not be intentional but is definitely a fact. When the commercial aquaculture started, women engaged in small scale aquaculture in small backyard ponds and who collected seed from the wild began to be side-lined. Their labour was found suitable in some activities, but very few of them could take advantage of the transformation and become aquaculturists having tenure rights over the farms. When ponds or reservoirs are leased out for fishing also, these are mostly to fishermen cooperatives or groups and though women are actively engaged in fishing in reservoirs they have no legal claim as fishers. The same applies to other development activities, like modernisation of markets, which does not take gender-specific needs into consideration in the development process; or upgradation of traditional processing methods like drying etc.

Recognising women's work in fisheries and aquaculture

In fish value chains, women are found in all nodes, unlike previously considered to dominate only post-harvest. While they are rare in industrial fishing, their contribution to fish production is significant in small scale fisheries (Harper et. al., 2022). This is also true in inland fish production and in aquaculture where women are involved in several key production activities. Women in several countries are engaged, along with the menfolk, in harvesting fish (Gopal and Ananthan, 2021) and later also marketing the harvested fish.

There is sparse documentation of this and very little recognition of these types of fishing activities in fish production data. This in turn leads to lack of recognition of women as fishers

and thus leads to exclusion from production oriented and welfare programmes and schemes implemented by the State. Women themselves do not feel that the work they do is actually a contributor to fish production and perceive it as supplementary to the fishing activities that the men are engaged in.

Women dominate fisheries post-harvest. Women are key links in fish reaching the consumer as they engage in fish retailing. Traditionally when fishing was still small scale women were key players in landing places with their work starting right from sorting catches to marketing fish and processing excess fish through traditional methods like drying, smoking, fermenting and pickling. Much of this work however was seen as extension of reproductive roles and was not considered economic activity (except for marketing which brought in cash incomes). The dried fish they help produce also had economic value, however marketing of this is generally taken over by men, and women deal with sale of smaller quantities. The traditional fermenting is still a women centric and the products have been an important ingredient in household diets ensuring protein availability, but marketing at commercial scale is now being carried out by men.

Ensuring equality in access – technology, credit, markets, skill upgradation, opportunities

Access to resources, technology, credit, markets and opportunities is essential to benefit from any economic activity. Traditional access that women had to common property resources like the fish, the beaches and economic activity spaces like markets is also being slowly lost. This is partly because of technology driven transformations in the sector which have bypassed fisherwomen. In marine fisheries for instance, fishing has become mechanized and is now carried out in farther and deeper waters over several days. Landings have also become centralised and harbour oriented from what was essentially at one time carried out in beaches near fishing villages. Though there are still several smaller beach landing centres, bulk of the landings have shifted to harbours, which are out of bounds for the women as they are located far away from fishing villages, commuting to which is additional expenditure. Women have also poor access to credit excluding them from the auctioning process. Women have thus been marginalised and now occupy fringe spaces in the points of first sale and have lost traditional access rights that they had to the fish which they used for household purposes as well for marketing domestically and processing if in excess and unsold. They now wait for their turn to source fish from larger traders or wholesalers before they can engage in marketing. Primary fish markets in India have space limitations considering the number of people frequenting them especially during peak landings which are generally confined to a few hours. All the jostling and pushing around also makes it physically perilous and unsafe for women.

Women in traditional aquaculture also made important contribution to household food security by producing for the family, besides for the market. Commercial aquaculture is basically monoculture or restricted to few commercially important species and is not available for the households of the labour force engaged in the activities. There are attempts to integrate tradition indigenous species into aquaculture systems so that these can be used for household consumption (Rai et. al., 2014), which can be adopted more widely in government schemes.

In formal wholesale and retail fish markets, which are owned by local bodies like municipalities or corporations or village governance bodies, and auctioned to private individuals, women have been relegated to insignificant places. There is growing male domination in fish retailing, and the women have to compete with the traders who can source frozen fish from other states and have a network to distribute them as also source fish locally due to links with the auctioners at the points of first sale. The marketing process may have become more efficient with the entry of bigger players with better resources and the demand in one place is being met by supply from another. However, women vendors who usually source fish on a day-to-day basis and deal in smaller volumes and operate in restricted areas are the ones being pushed out. Even today, basic facilities in markets like toilets are still non-existent; and rules like tax collection are arbitrary and opaque. These clearly disadvantage the women. Other externalities mentioned like inaccessibility of fish due to centralization of landings as opposed to landings closer to fishing villages, had already pushed women to the fringes of the distribution channels. Their bargaining power is also low and women vendors often get lower prices for the fish than male vendors (GAFS, 2018). Issues like harassment including difficulty in accessing public transport are common.

Dried fish production was primarily a women's job which was generally taken up during periods of excess catches that could not be absorbed into the fresh fish marketing chains. Sun drying on beaches was commonly practised and the dried fish sold during lean seasons for additional income and also used for household consumption. Beaches today have multiple uses and several stakeholders and the women are losing access to them. There is also sea erosion as a result of climate change and other anthropogenic activities. The shrinking spaces have made it difficult for women to engage in their traditional occupation. This has also led to nutritional insecurity of fisher households as they do not have sufficient access to fish to meet household food needs. This applies to both fresh and dried fish. While several technological innovations have been introduced for improving fish drying, like use of mechanical driers, the reach of these technologies to women is again constrained due to factors discussed above; lack of access to credit, training and technology.

Women also dominate seafood processing managing all floor-level processing activities. They are the backbone of the export-oriented industry globally. Disadvantages in wages and working conditions are common, and migrants who have very little say or negotiation skills dominate the labour market. The work is categorised unskilled and that is used as a reason to supress wages, with it being linked to piece/count or weight processed. The physical conditions are also taxing having to spend hours in cold and wet conditions which are potentially hazardous.

Where are the voices of fisherwomen?

Issues can come to the forefront only if the affected parties are allowed and have a space to voice them. No amount of advocacy on their behalf has an impact as much as when they speak for themselves. This can come about only if women have greater participation in decision-making at all levels. Often social and cultural norms impede women's participation, especially in matters that require decisions to be taken, whether at household or community levels. These norms are often difficult to change but have come about through legal provisions by the State.

For eg. the Panchayati Raj Act [The Constitution (Seventy-Third Amendment) Act, 1992] in India ensued that women got representation in local governance in India. This saw a change in women's participation in the political sphere, though several grass-roots level implementation issues remained and the question is whether it has brought about real change in socio-economic and political conditions (Mohanty, 1995). However over the years it has been noticed that the provisions of the Act has brought in several women to the forefront of local governance. A similar pattern is not reflected in women's participation in fisheries management related institutions, mainly because it is considered a male domain. Most cooperatives have male dominated management with women hardly finding space as board members participating in decision making (Gopal et al., 2017). It is important to have legal provisions to include women in organisations/institutions and affirmative action to implement them. Women can bring in their perspectives and understanding, including on resource management and conservation, especially their knowledge in small scale fisheries. Degradation and loss of biodiversity adversely affects fishing communities and women's perspectives are also equally important for sustainable development which has long term impacts on sustaining livelihoods and poverty reduction. The impacts of and response to shocks are also always gendered (Defiesta and Badayos-Jover, 2014) and women need to be included in the search for solutions as some of their needs are unique, although some might be common. When disasters strike men often migrate in search of livelihood and the women are responsible for meeting family needs. These call for greater inclusion of women in decision-making processes. There are also other inter-sectionalities at play, which may include religion, class and caste, that complicates inclusion.

There is also poor organisation of women workers in fisheries and aquaculture, and they function in the informal economy which continues to be unregulated. Women thus face exclusion from state schemes that would have benefitted them otherwise. The SHG model has been implemented by states and women SHGs have been formed and encouraged to take up productive activities. Another form of organisation includes membership in fisher cooperatives. Even in cooperatives the extent of credit support that women receive is proportionately less than the men. While men receive credit for purchase of fishing implements, women's credit schemes are often smaller in scale and they continue the same biases that they face socially, with their work considered supplementary to men's work. Productive activities are expected or assumed to be smaller and just above subsistence levels, rather than entrepreneurial. NGOs fill this space but their activities though important, tend to have localised impacts. The fish enterprises that women run are thus smaller and have limited scope for expansion commercially. Small scale vending or processing does not offer them the economies of scale to expand through further investments for upgradation. When the fishing and fish processing begins to get bigger, it is the men who dominate such

While women represented 39 per cent of world employment, only 27 per cent of managerial positions in the world were occupied by women in 2018, up only marginally from 26 per cent in 2015. The proportion of women in management has increased since 2000 in all regions except in least developed countries.

Source: https://sdgs.un.org/goals/goal5

enterprises. In a study on top levels of management in seafood factories, it was found that only 4 % of women reached the very top as CEOs (WSI, 2020), and even at levels below that they were in a minority. At the floor-level, 'unskilled' work was done almost entirely by women, both local and migrant. This floor-level work offers low wages and has no job security, with most women being hired on contractual basis.

Potential solutions and Action – integrating gender

Actions have to be looked at from various levels. An overarching policy to achieve the larger goal of gender equality in fisheries and aquaculture, for ensuring equity in opportunities and benefits from the sector is essential. Empowerment in terms of choices that are available to fisherwomen with regard to their livelihoods, involvement in decisions regarding the sector as a whole, and a say in matters that have a direct or indirect bearing on their lives is to be ensured.

From the policy perspective, before developing policies, programmes and schemes the existing activities and the actors (women and men) need to be clearly delineated and identified, and the impacts on each of these activities and actors needs to be assessed to factor-in alternatives. This can prevent the marginalisation of fisherwomen from fish value chains, as is increasingly being observed. Policies are always data driven and the invisibility of women stems from the lack of supporting data on their involvement in the sector. The need for collection of sex-disaggregated data in fisheries and aquaculture has been pointed out in several studies. Even when International bodies like FAO have mechanisms to collect such information, responses from nations are not uniform or adequate in many cases. At national level mechanism has to be evolved to streamline data generation so that there is standardisation and robustness is ensured leading to better policy and management decisions.

Legally there is also need for formal recognition as fish workers and equal access to benefits that will accrue from government schemes and from the activities that they are engaged in. Welfare Schemes require formal recognition as fishers and by excluding a large section of the community from this legal recognition, prevents equity in sharing of benefits that women are entitled to. There is need to ensure tenure rights for women in fishing and fish farming. This extends to rights to fish in reservoirs and other water bodies. Improving access to technology, capacity building, credit and other resources is required to ensure women's engagement in economic activity in fisheries and aquaculture. Job security, equal opportunities for growth, opportunities for collectivisation and action are all important.

Marketing is a domain where women work in large numbers. Streamlining marketing activities and infrastructure, and ensuring women safe and secure access to these spaces is very important. Sufficient access to credit to enable participation at all levels of marketing including primary markets is also to be ensured. To enable women to compete with male counterparts, skill development in using 2 and 3 wheelers that can extend there are of operation and can also be time saving is essential and specific State schemes are required for this. Access to modern marketing technologies and strategies is also essential that requires capacity building. Women are already on their own using mobile phones to reach consumers, but they can be equipped to enter into the e-marketing space. Women vendors need to ply their trade in safe and secure environment and this requires strong legal protection. Licensing

for fish vending work is to be introduced. Just like in marketing, in other activities along fish value chains, safe work spaces must be ensured so that women can carry out activities with dignity and confidence. New collectives or increased participation in existing collectives need to be built through State or non-State supported actions, so that the voices of women are reflected in decision-making in fisheries and aquaculture on all aspects as all activities affect the participation of women, either directly or indirectly.

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Data Mining and Computation Software for Improving Fisheries Research

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Introduction

The branch of science which deasls with data generation, management, analysis and information retrieval is called "Statistics". Statistics methods and advanced computational techniques are very important and crucial to fisheries research and management. Statistics has a key role to play in fisheries research carried out in the various disciplines viz., Aquaculture, Fisheries Resource Management, Fish Genetics, Fish Biotechnology, Aquatic Health, Nutrition, Environment, Fish Physiology and Post-Harvest Technology for enhancing production and ensuring sustainability. For formulating advisories and policies for stakeholders at all levels, the data generated from the various sub-sectors in fisheries and aquaculture has to be studied.

Statistical system can play more dominant role

- in providing tools for policy making and implementation
- in directing the impact of technology
- in sustaining the nutritional safety
- in socio-economic upliftment of people below poverty line
- to identify emerging opportunities through effective coordination
- speedy dissemination of information by networking and appropriate human resource development

Data Mining

Data mining refers to extracting or mining knowledge from large amounts of data. It is the computational process of discovering patterns in large data sets involving methods at the intersection of artificial intelligence, machine learning, statistics, and database systems. The overall goal of the data mining process is to extract information from a data set and transform it into an understandable structure for further use. The key properties of data mining are

- Automatic discovery of patterns
- Prediction of likely outcomes
- Creation of actionable information
- Focus on large datasets and databases

Data mining can generate new business opportunities when databases of sufficient size and quality, are analysed for patterns, and based on this action can be streamlined. Data mining automates the process of finding predictive information in large databases. Questions that traditionally required extensive hands on analysis can now be answered directly from the data — quickly. A typical example of a predictive problem is targeted marketing. Data mining uses data on past promotional mailings to identify the targets most likely to maximize return

on investment in future mailings. Other predictive problems include forecasting bankruptcy and other forms of default, and identifying segments of a population likely to respond similarly to given events.

Data mining is at the heart of analytics efforts across a variety of industries and disciplines. Telecom, media and technology In an overloaded market where competition is tight, the answers are often within your consumer data. Telecom, media and technology companies can use analytic models to make sense of mountains of customers data, helping them predict customer behaviour and offer highly targeted and relevant campaigns.

Education With unified, data-driven views of student progress, educators can predict student performance before they set foot in the classroom – and develop intervention strategies to keep them on course. Data mining helps educators access student data, predict achievement levels and pinpoint students or groups of students in need of extra attention.

Finance & banking Automated algorithms help banks understand their customer base as well as the billions of transactions at the heart of the financial system. Data mining helps financial services companies get a better view of market risks, detect fraud faster, manage regulatory compliance obligations and get optimal returns on their marketing investments.

Insurance With analytic know-how, insurance companies can solve complex problems concerning fraud, compliance, risk management and customer attrition. Companies have used data mining techniques to price products more effectively across business lines and find new ways to offer competitive products to their existing customer base.

Manufacturing Aligning supply plans with demand forecasts is essential, as is early detection of problems, quality assurance and investment in brand equity. Manufacturers can predict wear of production assets and anticipate maintenance, which can maximize uptime and keep the production line on schedule.

Retailing Large customer databases hold hidden customer insight that can help you improve relationships, optimize marketing campaigns and forecast sales. Through more accurate data models, retail companies can offer more targeted campaigns – and find the offer that makes the biggest impact on the customer.

Data mining tools sweep through databases and identify previously hidden patterns in one step. An example of pattern discovery is the analysis of retail sales data to identify seemingly unrelated products that are often purchased together. Other pattern discovery problems include detecting fraudulent credit card transactions and identifying anomalous data that could represent data entry keying errors.

Data can be of the following types - Record data – Transactional, Temporal data – Time series, sequence (biological sequence data), Spatial & Spatial-Temporal data, Graph data, Unstructured data -twitter, status, review, news article and Semi-structured data -publication data, xml. Data mining can be employed for:

Anomaly detection (Outlier/change/deviation detection) – The identification of unusual data records, that might be interesting or data errors that require further investigation.

Association rule learning (Dependency modelling) – Searches for relationships between variables. For example a supermarket might gather data on customer purchasing habits. Using association rule learning, the supermarket can determine which products are frequently bought together and use this information for marketing purposes. This is sometimes referred to as market basket analysis.

Clustering – is the task of discovering groups and structures in the data that are in some way or another "similar", without using known structures in the data.

Classification – is the task of generalizing known structure to apply to new data. For example, an e-mail program might attempt to classify an e-mail as "legitimate" or as "spam".

Regression – attempts to find a function which models the data with the least error.

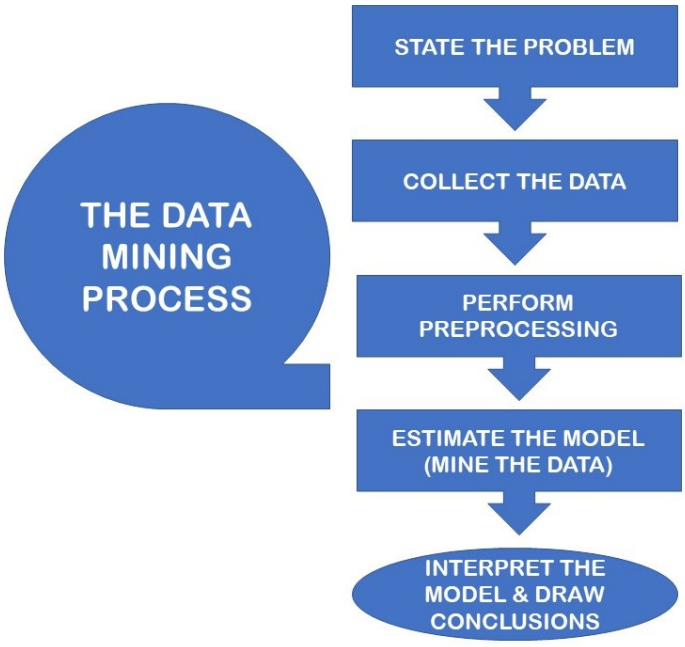
Summarization – providing a more compact representation of the data set, including visualization and report generation.

The Data Mining Process

In order to explore the unknown underlying dependency in the data an initial hypothesis is assumed. There may be several hypotheses formulated for a single problem at this stage. Data generation is the second step which can be either through a designed experiment. The second possibility is when the expert cannot influence the data- generation process: this is known as the observational approach. An observational setting, namely, random data generation, is assumed in most data-mining applications. Data collection affects its theoretical distribution. It is important to make sure that the data used for estimating a model and the data used later for testing and applying a model come from the same, unknown, sampling distribution. In the observational setting, data are usually "collected" from the existing databases, data warehouses, and data marts.

Data pre-processing is an important step before doing the analysis. Firstly outliers have to be identified and removed or treated. Commonly, outliers result from measurement errors, coding and recording errors, and, sometimes, are natural, abnormal values. Such nonrepresentative samples can seriously affect the model produced later. Pre-processing involves either removal of outliers from data or develop robust models which are insensitive to outliers. Data pre-processing also includes several steps such as variable scaling and different types of encoding. For estimating the model, selection and implementation of the appropriate data-mining technique is an important step.

Data-mining models should help in decision making. Hence, such models need to be interpretable in order to be useful because humans are not likely to base their decisions on complex "black-box" models. Note that the goals of accuracy of the model and accuracy of its interpretation are somewhat contradictory.



Usually, simple models are more interpretable, but they are also less accurate. Modern data-mining methods are expected to yield highly accurate results using high dimensional models.

Data Mining Techniques

Important data mining techniques are

- Classification analysis. This analysis is used to retrieve important and relevant information about data, and metadata
- Association rule learning
- Anomaly or outlier detection
- Clustering analysis
- Regression analysis

Association analysis is the finding of association rules showing attribute-value conditions that occur frequently together in a given set of data. Association analysis is widely used for a market basket or transaction data analysis. Association rule mining is a significant and exceptionally dynamic area of data mining research. One method of association-based classification, called associative classification, consists of two steps. In the main step, association instructions are generated using a modified version of the standard association rule mining algorithm known as A priori. The second step constructs a classifier based on the association rules discovered.

Classification is the processing of finding a set of models (or functions) that describe and distinguish data classes or concepts, for the purpose of being able to use the model to predict the class of objects whose class label is unknown. Data Mining has a different type of classifier:

- Decision Tree - a flow-chart-like tree structure, where each node represents a test on an attribute value, each branch denotes an outcome of a test, and tree leaves represent classes or class distributions.
- SVM(Support Vector Machine) - is a supervised learning strategy used for classification and additionally used for regression. When the output of the support vector machine is a continuous value, the learning methodology is claimed to perform regression; and once the learning methodology will predict a category label of the input object, it's known as classification.
- Generalized Linear Models - is a statistical technique, for linear modeling.GLM provides extensive coefficient statistics and model statistics, as well as row diagnostics. It also supports confidence bounds.
- Bayesian classification - is a statistical classifier. They can predict class membership probabilities, for instance, the probability that a given sample belongs to a particular class. Bayesian classification is created on the Bayes theorem.
- Classification by Backpropagation
- K-NN Classifier - The k-nearest neighbor (K-NN) classifier is taken into account as an example-based classifier, which means that the training documents are used for comparison instead of an exact class illustration, like the class profiles utilized by other classifiers.
- Rule-Based Classification - represent the knowledge in the form of If-Then rules. An assessment of a rule evaluated according to the accuracy and coverage of the classifier. If more than one rule is triggered then we need to conflict resolution in rule-based classification.
- Frequent-Pattern Based Classification - (or FP discovery, FP mining, or Frequent itemset mining) is part of data mining. It describes the task of finding the most frequent and relevant patterns in large datasets.
- Rough set theory - can be used for classification to discover structural relationships within imprecise or noisy data. It applies to discrete-valued features. Continuous-valued attributes must therefore be discrete prior to their use. Rough set theory is based on the establishment of equivalence classes within the given training data.
- Fuzzy Logic - Rule-based systems for classification have the disadvantage that they involve sharp cut-offs for continuous attributes. Fuzzy Logic is valuable for data mining frameworks performing grouping /classification. It provides the benefit of working at a high level of abstraction.

Clustering Unlike classification and prediction, which analyze class-labelled data objects or attributes, clustering analyzes data objects without consulting an identified class label. In general, the class labels do not exist in the training data simply because they are not known to begin with. Clustering can be used to generate these labels. The objects are clustered based on the principle of maximizing the intra-class similarity and minimizing the interclass similarity. That is, clusters of objects are created so that objects inside a cluster have high similarity in contrast with each other, but are different objects in other clusters. Each Cluster

that is generated can be seen as a class of objects, from which rules can be inferred. Clustering can also facilitate classification formation, that is, the organization of observations into a hierarchy of classes that group similar events together.

Regression can be defined as a statistical modelling method in which previously obtained data is used to predicting a continuous quantity for new observations. This classifier is also known as the Continuous Value Classifier. There are two types of regression models: Linear regression and multiple linear regression models.

Data Generation in Fisheries

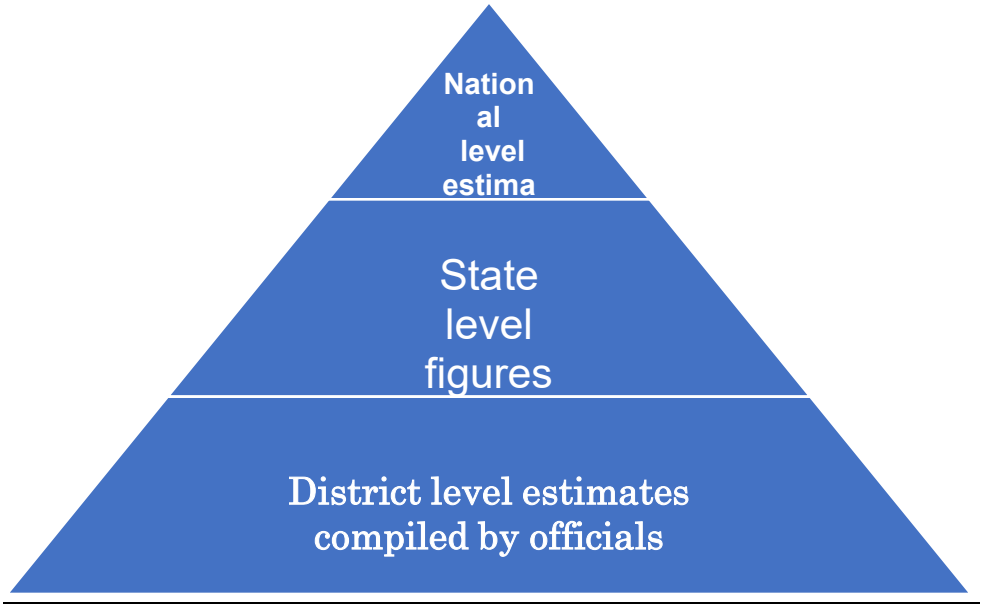
Date generation in fisheries will vary depending on the nature of research undertaken. For example, when species behaviour, growth, abundance, etc. is studied detailed data on spatial distribution and catch is required. If the focus is to predict the profit of the coming years, an economist should study the effect of population size on producer's costs. The macro level data on infrastructure, employment, earnings, investment etc. will be considered to formulate management measures. Enormous data from marine fishing gets generated from commercial fishing vessels and research vessels which will can be mined to analyse the trend, resource abundance, etc.

In 'Fishery technology' large volumes of data generated in a wide range of applied scientific areas of fishing technology, fish processing, quality control, fishery economics, marketing and management. Apart from statistical data collected in technological research, data also collected on production, export, socio-economics etc. for administrative and management decision making.

Major areas of data generation:

- fishing vessel and gear designs
- fishing methods
- craft and gear materials
- craft and gear preservation methods
- fishing efficiency studies
- fishing accessories
- emerging areas include use of GIS and remote sensing

Data on various aspects of fishing gets collected for administrative purposes and policy making. For administrative purposes, voluminous data gets generated through fisheries departments of states. Each district has officials entrusted with the work of collection of data which are coordinated at the state level. State level figures are compiled at the National level by Department of Animal Husbandry and Dairying, Ministry of Agriculture, New Delhi.



Information is also compiled on macro economic variables like GSDP from fishing by the respective Directorates of Economics & Statistics.

Infrastructure

Indian fisheries is supported by a vast fishing fleet of 2,03,202 fishing crafts categorized into mechanized, motorized and non-motorised. The registration of these fishing crafts are done at various ports across India and license for fishing operations has to be obtained from the respective states. The fish processing sector largely managed by the private sector has per day processing capacity installed at 11000 tonnes per day. Data is also collected on the infrastructure facilities and inventories by agencies from time to time such as number of mechanized, motorized and non-motorized fishing crafts, fish landing centers, fisheries harbours, types of gears and accessories, fish markets, ice plants and cold storages, Socio-economic data like population of fishermen, welfare schemes, cooperative societies, financial assistance, subsidies, training programs, etc.

Fish Landings and fishing effort

Indian fisheries has seen tremendous development over the past six decades owing to technology changes in fishing like mechanization of propulsion, gear and handling, introduction of synthetic gear materials, development of acoustic fish finding devices, satellite based fish detection techniques, advances in electronic navigation and communication equipment. The increase in fish production can be said as exponential with a mere 75000 MT in 1950-51 to 11.42 million MT in the current year. Both marine fisheries and aquaculture have contributed to the present level of production with share from culture fisheries more than the capture fisheries. It is important task to collect macro level data from state and country on fish production and details of the species caught in the sea.

The data on fish catch and effort (a measure of fishing activity of vessels at sea), from all the coastal states, Union territories, Islands is being done by ICAR-Central Marine Fisheries

Research institute and maintained as database. Based on standard sampling methodology developed by CMFRI, daily data on commercial landings from selected centres/zones all over the coast is collected, compiled and published. Detailed time series data has been generated on species wise, region wise, gear wise fish landings are collected and compiled for the use of researchers and policy makers. The beach price of fish (species wise) is also collected periodically.

Data on fish farms, production and area under aquaculture is maintained by the respective State Fisheries departments and compiled at the National level. Apart from capture fisheries (marine) and culture fisheries (aquaculture) the fish production from inland water bodies like lake, ponds, reservoirs, etc. is collected and compiled at State level. For developing the sector, various programmes and projects have to be formulated and implemented. To achieve the objectives of such developmental programmes, the current status of production of fish from various regions has to be made known. The need for fish production data maintained by these agencies from marine sources, aquaculture and inland water bodies arises while formulating various research studies and development projects at district, state and National level.

Data generation along the fish value chain

Fresh fish after harvest is iced and distributed through various channels into the domestic markets and overseas markets. Around 80% of the fish is marketed fresh, 12% of fish gets processed for the export sector, 5% is sent for drying/curing and the rest is utilized for other purposes.

Marine Products Export Development Authority (MPEDA) maintains the database on export of fish and fishery products from India to various country. The weekly prices realized by Indian seafood products in the various overseas markets are also collected and compiled by the agency. Marine Products Export Development Authority (MPEDA) established in 1972 under the Ministry of Commerce responsible for collecting data regarding production and exports, apart from formulating and implementing export promotion strategies. Prior to the establishment of MPEDA, Export Promotion Council of India was undertaking this task.

Fish processing factories established all over the country generate data on daily production, procurement of raw material and movement of price structure etc. which is generally kept confidential.Data on quality aspects maintained by Export Inspection Council of India through Export Inspection Agency (EIA) in each region, under Ministry of Commerce and Industry. The EIA is the agency approving the suitability of the products for export.

- bacteriological organisms present in the products
- rejections in terms of quantity
- reason for rejection etc.

Fish quality control

Other types of data generated by CIFT in fishing and fish processing technology are quality control data on fish and fishery products, ice, water, etc. Offshoot of processing technology is Quality Control of which Statistical Quality Control forms an integral part. Due to the stringent quality control measures imposed by importing countries, especially the EU and USFDA standards samples of fish and related products like raw materials, ice and water samples and swabs from fish processing factories are tested at the quality control labs. Another area where statistics gets generated is in product development : consumer acceptability and preference studies mainly for value-added products. Using statistical sensory evaluation methods this data gets analysed.

At Central Institute of Fisheries Technology (CIFT) we are periodically collecting data on the following aspects which is used for policy decisions

- Techno-economic data on various technologies developed
- Data on Economics of operation of mechanized, motorized and traditional crafts
- Data for the estimation of fuel utilization by the fishing industry
- Year wise data on Installed capacity utilization in the Indian seafood processing industry
- Demand – supply and forecast studies on the fishing webs
- Harvest and post-harvest losses in fisheries
- Transportation of fresh fish and utilization of trash fish
- Impact of major trade policies like impact of anti-dumping, trend analysis of price movement of marine products in the export markets
- Study on impact of technology and study on socio-economic aspects

Computational Software for Fisheries Research

R is an open source software that provides a programming environment for doing statistical data analysis. R can be effectively used for data storage, data analysis and a variety of graphing functions. R works on the principle of 'functions' and objects. There are about 25 packages supplied with R (called "standard" and "recommended" packages) and many more are available through the CRAN family of Internet sites (via https://CRAN.R-project.org) and elsewhere. It gets widely used for analysing fisheries data. Also SAS software which

Data Mining Software

Compared to other data mining software, SAS Enterprise Miner is a very comprehensive tool that can handle a wide variety of data mining tasks. Further, it is very user-friendly and easy to learn, even for users who are not familiar with SAS programming. Finally, it has a wide range of built-in features and functionality, which makes it a very powerful tool.

Data mining using SAS

SAS Enterprise Miner is a software tool from SAS that is used for data mining and predictive modelling. It provides a graphical user interface for easy access to a variety of data mining

and machine learning algorithms, and can be used to build predictive models from data sets of any size.

Features:

- SAS Data mining tools help you to analyze Big data
- It is an ideal tool for Data mining, text mining & optimization.
- SAS offers distributed memory processing architecture which is highly scalable

The process flow of SAS Enterprise Miner is as follows:

1. Data is imported into the project.
2. A model is created using the data.
3. The model is validated and deployed.

Data preparation

Data input

You can load a dataset into SAS Enterprise Miner by using the Data Import node. This node allows you to specify the location of the dataset, as well as any other necessary information such as variable types and roles. Nodes are the building blocks of a SAS Enterprise Miner process flow. There are a variety of node types, each of which performs a different task. For example, there are nodes for data import, data cleansing, modelling, and results visualization. The main components of SAS Enterprise Miner are the data source, the data target, the model, and the results. The data source is the location from which the data is being imported. The data target is the location to which the data is being exported. The model is the statistical or machine learning model that is being used to analyze the data. The results are the output of the model, which can be used to make predictions or decisions.

Decision trees are a type of predictive modeling that can be used to classify data. In SAS Enterprise Miner, decision trees are generated using the Tree Model node. This node takes a dataset as input and generates a decision tree based on the variables in the dataset. The tree can then be used to predict the class of new data.

Data partition

You can split datasets in SAS Enterprise Miner by using the Partition node. This node will take a dataset as input and will output two or more partitions, based on the settings that you specify. You can specify the percentage of records that should go into each partition, or you can specify a particular variable to split the dataset on. Partitioning provides mutually exclusive data sets. Two or more mutually exclusive data sets share no observations with each other. Partitioning the input data reduces the computation time of preliminary modelling runs.

The Data Partition node enables you to partition data sets into training, test, and validation data sets. The training data set is used for preliminary model fitting. The validation data set is used to monitor and tune the model weights during estimation and is also used for model assessment. The test data set is an additional hold-out data set that you can use for model

assessment. This node uses simple random sampling, stratified random sampling, or user-defined partitions to create partitioned data sets.

Filtering data

The Filter node tool is located on the Sample tab of the Enterprise Miner tools bar. Use the Filter node to create and apply filters to your training data set. You can also use the Filter node to create and apply filters to the validation and test data sets. You can use filters to exclude certain observations, such as extreme outliers and errant data that you do not want to include in your mining analysis. Filtering extreme values from the training data tends to produce better models because the parameter estimates are more stable.

Explore Node of SAS Enterprise miner

Association node enables you to identify association relationships within the data. For example, if a customer buys a loaf of bread, how likely is the customer to also buy a gallon of milk? The node also enables you to perform sequence discovery if a sequence variable is present in the data set. • The Cluster node enables you to segment your data by grouping observations that are statistically similar. Observations that are similar tend to be in the same cluster, and observations that are different tend to be in different clusters. The cluster identifier for each observation can be passed to other tools for use as an input, ID, or target variable. It can also be used as a group variable that enables automatic construction of separate models for each group.

DMDB node creates a data mining database that provides summary statistics and factor-level information for class and interval variables in the imported data set. The DMDB is a metadata catalog used to store valuable counts and statistics for model building.

Graph Explore node is an advanced visualization tool that enables you to explore large volumes of data graphically to uncover patterns and trends and to reveal extreme values in the database. For example, you can analyze univariate distributions, investigate multivariate distributions, and create scatter and box plots and constellation and 3-D charts. Graph Explore plots are fully interactive and are dynamically linked to highlight data selections in multiple views.

Link Analysis node transforms unstructured transactional or relational data into a model that can be graphed. Such models can be used to discover fraud detection, criminal network conspiracies, telephone traffic patterns, website structure and usage, database visualization, and social network analysis. Also, the node can be used to recommend new products to existing customers.

Market Basket node performs association rule mining over transaction data in conjunction with item taxonomy. This node is useful in retail marketing scenarios that involve tens of thousands of distinct items, where the items are grouped into subcategories, categories,

departments, and so on. This is called item taxonomy. The Market Basket node uses the taxonomy data and generates rules at multiple levels in the taxonomy.

MultiPlot node is a visualization tool that enables you to explore larger volumes of data graphically. The MultPlot node automatically creates bar charts and scatter plots for the input and target variables without making several menu or window item selections. The code created by this node can be used to create graphs in a batch environment.

Path Analysis node enables you to analyze Web log data to determine the paths that visitors take as they navigate through a website. You can also use the node to perform sequence analysis.

SOM/Kohonen node enables you to perform unsupervised learning by using Kohonen vector quantization (VQ), Kohonen self-organizing maps (SOMs), or batch SOMs with Nadaraya-Watson or local-linear smoothing. Kohonen VQ is a clustering method, whereas SOMs are primarily dimension-reduction methods.

StatExplore node is a multipurpose node that you use to examine variable distributions and statistics in your data sets. Use the StatExplore node to compute standard univariate statistics, to compute standard bivariate statistics by class target and class segment, and to compute correlation statistics for interval variables by interval input and target. You can also use the StatExplore node to reject variables based on target correlation.

Variable Clustering node is a useful tool for selecting variables or cluster components for analysis. Variable clustering removes collinearity, decreases variable redundancy, and helps reveal the underlying structure of the input variables in a data set. Large numbers of variables can complicate the task of determining the relationships that might exist between the independent variables and the target variable in a model. Models that are built with too many redundant variables can destabilize parameter estimates, confound variable interpretation, and increase the computing time that is required to run the model. Variable clustering can reduce the number of variables that are required to build reliable predictive or segmentation models.

Variable Selection node enables you to evaluate the importance of input variables in predicting or classifying the target variable. The node uses either an R2 or a Chi-square selection (tree based) criterion. The R-square criterion removes variables that have large percentages of missing values, and remove class variables that are based on the number of unique values. The variables that are not related to the target are set to a status of rejected. Although rejected variables are passed to subsequent tools in the process flow diagram, these variables are not used as model inputs by modelling nodes such as the Neural Network and Decision Tree tools.

Modelling Data using SAS Enterprise miner

AutoNeural node can be used to automatically configure a neural network. The AutoNeural node implements a search algorithm to incrementally select activation functions for a variety of multilayer networks.

Decision Tree node enables you to fit decision tree models to your data. The implementation includes features found in a variety of popular decision tree algorithms (for example, CHAID, CART, and C4.5). The node supports both automatic and interactive training. When you run the Decision Tree node in automatic mode, it automatically ranks the input variables based on the strength of their contribution to the tree. This ranking can be used to select variables for use in subsequent modelling. You can override any automatic step with the option to define a splitting rule and prune explicit tools or subtrees. Interactive training enables you to explore and evaluate data splits as you develop them.

Dmine Regression node enables you to compute a forward stepwise least squares regression model. In each step, the independent variable that contributes maximally to the model R-square value is selected. The tool can also automatically bin continuous terms.

DMNeural node is another modelling node that you can use to fit an additive nonlinear model. The additive nonlinear model uses bucketed principal components as inputs to predict a binary or an interval target variable with automatic selection of an activation function.
Ensemble node enables you to create new models by combining the posterior probabilities (for class targets) or the predicted values (for interval targets) from multiple predecessor models.

Gradient Boosting node uses tree boosting to create a series of decision trees that together form a single predictive model. Each tree in the series is fit to the residual of the prediction from the earlier trees in the series. The residual is defined in terms of the derivative of a loss function. For squared error loss with an interval target, the residual is simply the target value minus the predicted value. Boosting is defined for binary, nominal, and interval targets.
LARS node enables you to use Least Angle Regression algorithms to perform variable selection and model fitting tasks. The LARs node can produce models that range from simple intercept models to complex multivariate models that have many 65 inputs. When using the LARs node to perform model fitting, the node uses criteria from either least angle regression or the LASSO regression to choose the optimal model.

MBR (Memory-Based Reasoning) node enables you to identify similar cases and to apply information that is obtained from these cases to a new record. The MBR node uses k-nearest neighbor algorithms to categorize or predict observations.

Model Import node enables you to import models into the SAS Enterprise Miner environment that were not created by SAS Enterprise Miner. Models that were created by using SAS PROC LOGISTIC (for example) can now be run, assessed, and modified in SAS Enterprise Miner.

Neural Network node enables you to construct, train, and validate multilayer feedforward neural networks. Users can select from several predefined architectures or manually select input, hidden, and target layer functions and options.

Partial Least Squares node is a tool for modelling continuous and binary targets based on SAS/STAT PROC PLS. The Partial Least Squares node produces DATA step score code and standard predictive model assessment results.

Regression node enables you to fit both linear and logistic regression models to your data. You can use continuous, ordinal, and binary target variables. You can use both continuous and discrete variables as inputs. The node supports the stepwise, forward, and backward selection methods. A point-and-click interaction builder enables you to create higher-order modelling terms.

Rule Induction node enables you to improve the classification of rare events in your modelling data. The Rule Induction node creates a Rule Induction model that uses split techniques to remove the largest pure split node from the data. Rule Induction also creates binary models for each level of a target variable and ranks the levels from the most rare event to the most common. After all levels of the target variable are modelled, the score code is combined into a SAS DATA step.

Two Stage node enables you to compute a two-stage model for predicting a class and an interval target variable at the same time. The interval target variable is usually a value that is associated with a level of the class target.

Survival data mining

Survival data mining is the application of survival analysis to data mining problems that concern customers.. The application to the business problem changes the nature of the statistical techniques. The issue in survival data mining is not whether an event will occur in a certain time interval, but when the next event will occur. The SAS Enterprise Miner Survival node is located on the Applications tab of the SAS Enterprise Miner tool bar. The Survival node performs survival analysis on mining customer databases when there are time-dependent outcomes. The time-dependent outcomes are modelled using multinomial logistic regression. The discrete event time and competing risks control the occurrence of the time-dependent outcomes.

The Survival node includes functional modules that prepare data for mining, that expand data to one record per time unit, and perform sampling to reduce the size of the expanded data without information loss. The Survival node also performs survival model training, validation, scoring, and reporting.

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