Chapter 1

Indian fisheries: Harvest and Post-Harvest Scenario

Dr. Ravishankar, C.N.
cnrs2000@gmail.com
Director, ICAR-Central Institute of Fisheries Technology,
Matsyapuri P.O., Cochin- 682 029

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

Technological developments in harvest sector

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

Environmental protection and eco-friendly technologies for harvest sector

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

utilized wood and gives a durable, maintenance-free boat at affordable cost to the poor (Fig.1).

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

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

Harvest technologies for responsible fishing

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

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

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

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

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

reach of conventional bottom trawls, currently used in commercial trawl fisheries in India.

Harvest technologies for the traditional sector

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

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

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

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

Harvest technologies for the mechanized sector

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

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

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

Standardized the parameters to exploit semi-pelagic fishery resources.

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

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

Harvest technologies for the inland fisheries sector

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

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

Technological developments in post harvest sector

Preservation and processing aids

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

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

products against 12% of the cured product proportion in world fish production.

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

Smart processing and packaging technologies - A leap towards energy efficiency

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

food macromolecules that help the processor to have outstanding quality, with reduced cost, time and energy. The new technologies now introduce more possibilities in non-thermal or mild heat alternatives to the conventional heat processing.

High pressure processing:

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

Pulse light technology:

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

Pulse electric field technology:

PEF uses high voltage short pulses to preserve the food, so as to inactivate microbes with minimal effect on quality attributes of the product. It is one of the most appealing technology due to short treatment time (typically below 1 second); hence, foods treated this way retain their fresh aroma, taste, and appearance. It is suitable for preserving liquid and semi-liquid foods. Application of PEF technology has been successfully demonstrated for the pasteurization of foods fish soups, tomato juice and liquid eggs. Application of PEF processing is restricted to food products with no air bubbles and with low electrical conductivity. PEF is a continuous processing method, which is not suitable for solid food products that cannot be pumped.

Irradiation:

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

Ultrasound Processing:

The application of ultrasound in food processing is another area in non thermal approaches, which exploits the preservative effect of the high

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

Microwave processing:

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

Modified Atmosphere Packaging:

Modified atmosphere packaging is a technologically viable method to extend the storage life of fresh seafood products. In modified atmosphere packaging air is replaced with different gas mixtures to regulate microbial activity and /or retard discolouration of the products. The composition of the gas mixture changes from its initial composition as a result of chemical, enzymatic and microbial activity of the product during storage. It is primarily the enrichment of carbon dioxide in the storage atmosphere as a means of controlling microbial growth, which results in the extension of shelf life of products. Packaging materials generally employed for this purpose are flexible films of nylon/surylyn laminates, PVC moulded trays laminated with polythene, polyester/low density polythene film etc. The use of high barrier film along with MAP that contains CO_2 effectively inhibits bacterial growth during refrigerated storage of packaged fresh fishery products. On the other hand, oxygen can inhibit the growth of strictly anaerobic bacteria like *Clostridium botulinum* although there is a very wide variation in the sensitivity of anaerobes to Oxygen. It is also seen that inclusion of only some Oxygen with Nitrogen or Carbon dioxide will not prevent botulism with absolute certainty.

Active packaging system:

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

Intelligent packaging systems:

Intelligent packaging systems provide the user with information on the conditions of the food or its environment. It is a packaging system that is capable of carrying out intelligent functions (such as detecting,

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

Smart packaging system:

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

Value addition – processor's opportunity:

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

Fish mince and mince-based products:

Fish mince separated from skin, bone and fins are used for preparation of a variety of ready to eat/fry products. Battered and breaded products commonly known as 'coated products' like fish fingers, fish balls, cutlet, patties etc. are the most popular among them. Battering and

breading techniques have contributed significantly to value addition of fish and fishery products. These products fetch good demand in domestic as well as export markets as theyrequire minimum financial requirement and are affordable to low time traders.

Surimi and surimi-based products:

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

Thermal processing and ready to serve products:

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

Extruded snack products:

Extrusion helps to improve the versatility for the development of high-nutritive, low cost and convenient food products. It is a thermodynamically efficient process and ensures the destruction of bacteria and anti-nutritional factors during extrusion process. Flavour, texture and taste are the major characteristics affecting the acceptability of these products. Usually, extruded products are prepared using cereal

flour, which have less protein content and are limited in some essential amino acids. By incorporating protein-rich fish mince instead of cereal, the product is protein enriched snack food. 'Fish cure' is such a product developed by ICAR-CIFT with fish mince as base material. The flavour and taste of these products may be altered by coating with suitable spice/flavour mix. The production process involves mixing of fish mince with cereal flours, spices and salt and extrusion using a twin screw extruder (Fig.8). The dried and coated products are then packed in metalized polyester polyethylene pouches using nitrogen gas filling. The product is acceptable up to 3 months at ambient temperature.

Seaweed incorporated products:

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

Fish nutritional bars:

The new life styles of consumers add to the requirement of new health foods and nutritional energy supplements, in pleasing and portable way. Modern market, have gained a more attraction towards the convenient type nutritional bars/ energy bars/ protein bars in various forms and wide varieties can be made on the basis of different consumer requirement of health food, diet replacer, work out food, energy supplement, geriatric food, sugar free product and nutrient requirement for children. Globally, this trend is being driven by growing consumer awareness about better nutrition in physical performance and personal appearance. ICAR-CIFT has standardized some formulations for nutritional bars added with the best quality supplements from fish source. The protein from fish has been regarded as the high quality with well-balanced amino acid profile, that is easily digestible than any mammalian counter parts. ICAR-CIFT has developed a nutrient

formulation with cereal mixes, dried fruits fortified with different biomolecules like high profile fish protein/ collagen peptide/ omega-3 oil in crunchy type granola bars with good shelf stability. Fortification of 10-15% fish protein alone and provide an average energy of 400 Kcal/100g was achieved (Fig.10).

Processed fish roe and caviar substitutes:

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

Miscellaneous products:

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

High value byproducts - Wealth from waste

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

Fish meal:

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

Fish protein hydrolysate:

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

effectively reduced oil absorption in breaded and battered products, when incorporated in the batter mix.

Fish collagen/gelatin/collagen peptides:

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

Chitin:

The shrimp processing industry in India churns out more than 2 lakh tones of head and shell waste per annum, which can be economically converted to chitin and its derivatives. Chitin is the most abundant polymer next to cellulose. It is a linear polymer of N acetyl-D-glucosamine. Glucosamine hydrochloride can be produced from chitin by hydrolysis. Glucosamine hydrochloride and sulphate are at present marketed as food supplement for the treatment of osteoarthritis. It also possesses other beneficial actions in wound healing and skin moisturization. The

deacetylated chitin is known as chitosan. Chitin and chitosan have various applications in agriculture such as in germination of seeds and enhanced protection against pathogenic organisms in plants and suppress them in soil to induce chitinase activity and protenase inhibition, antivirus activity, in micro encapsulationfertilizersandinsecticides. The delivery of drugs and the interactions with living tissues seem to be the major topics of current research on chitosan. Other areas of interest are the antimicrobial action, nerve regeneration, cartilage and bone regeneration, skin and bone substitutes, oral delivery for wound healing etc. Carboxy methylation of chitosan imparts water-solubility to chitosan. ICAR-CIFT has recently standardised the methodology for production of chitin, glucosamine hydrochloride, chitosan and carboxymethyl chitosan. Similarly, collagen-chitosan film from fish waste, developed by the Institute has wide applications in wound dressing and dental surgery.The antioxidant chitosan derivative developed was found to be useful in micro-encapsulating vitamins and ß carotene, so as to give a novel delivery system. Similarly, a biocompatible and biodegradable wound healing formulation, composed of microencapsulated curcumin and hydrogel composite (Succinyl chitosan-fish collagen-poly ethylene glycol) developed at ICAR-CIFT, showed significantly enhanced rate of collagen deposition and hydroxyproline content in wound tissue on 14th day of post wounding as compared to control and standard. Apart from that, free radical mediated grafting of gallic acid, ferulic acid, vanillic acid and coumaric acid onto chitosan were optimised. All the derivatives showed good antioxidant and antimicrobial activities.

Fish ensilage and foliar spray:

When the animal farms are very near to fish landing centres it is worthwhile to go for silage production. Fish silage is made from whole fish or parts of the fish to which no other material has been added other than an acid and in which liquefaction of the fish is brought about by enzymes already present in the fish. The product is a stable liquid with a malty odour which has very good storage characteristics and contains all the water present in the original material. It is a simple process and it requires little capital equipment particularly if non-oily fish are used. The use of oily fish usually requires oil separation. This involves expensive equipment and is suited to a fairly large-scale operation. The silage may be suitable converted to foliar spray, as foliar feeding is an effective method for correcting soil deficiencies and overcoming the soils inability to transfer nutrients to the plant. The experiments conducted at ICAR-CIFT have shown that foliar feeding can be 8 to 10 times more effective than soil feeding and up to 90 percent of foliar fed nutrients. The application of

foliar spray has been advocated in spices like cardamom, black pepper, tea etc and encouraging results have been reported. The quick absorption of the nutrients and precise dosage of foliar sprays has resulted in the success of precision farming of costly vegetables and flowering plants. The controlled nutritional supply through praying is an effective method which gives predicted resulted in most of the cases. The optimized supply of required micro and macro nutrients results in the maximum productivity of the available space and minimizes the wastage of costly inputs.

Fish calcium:

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

Chondroitin Sulphate:

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

Squalene:

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

Hydroxyapatite (HAp):

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

Pigments:

Astaxanthin, fucaxanthin, melanin etc. from different fish resources are found to have a variety of bioactive properties. The filleting discards of salmonids and the shell wastes of crustaceans contain significant

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

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

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

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

Conclusion

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

Fig.1. Rubber wood canoe

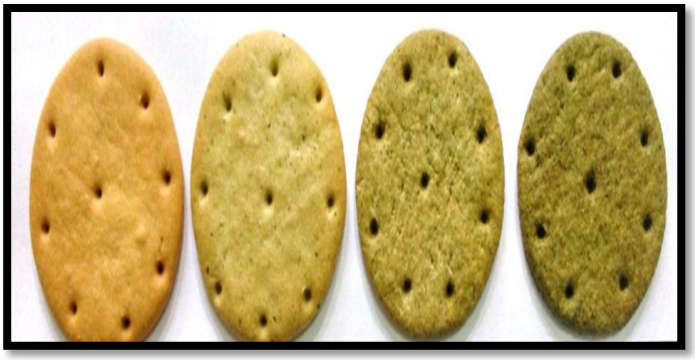
Fig.2. Solar-powered boat useful for aquaculture etc

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

Fig.4. Solar dyer

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

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



Seaweed enriched biscuits developed at ICAR-CIFT

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