e-Training Manual on

Recent Advances in Harvest and Post-Harvest Technologies in Fisheries

28 October - 10 November 2021

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on

Recent Advances in Harvest and Post-Harvest Technologies in Fisheries

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FOREWORD

Fisheries, in recent years, has emerged as one of the booming sectors in agriculture and allied field and gained enormous attention owing to its role in increasing food supply, improving nutritional status, maintaining livelihood security and accelerating the economy through huge foreign exchange earnings. Fisheries sector establishes its importance by contributing immensely towards the social and economic well-being of human beings in developing countries. It has been recognized as a potential livelihood option for income and employment generation as it stimulates growth of a number of subsidiary industries and is a potential source of affordable and high-quality protein to the population. Of late, the sector is facing several challenges and risks in the path of its growth with respect to some pertinent issues like enhanced productivity, increased profitability, exorbitant competitiveness and declined sustainability. Hence, there is need to provide apt solutions to these problems through technological advancements and innovations in the field of fisheries starting from production to consumption i.e. 'tide to table'. Innovations in fisheries involve research and technologies in capture and culture fish, advances in fishing, modern fish processing techniques, nutraceuticals development, fish waste utilization, fish health management, maintenance of safety and quality standards along with good marketing practices, mainstreaming with relevant social issues in fisheries and adoption of novel extension approaches to promote and popularize these innovations for sustainable development of fisheries. Cross learning of these innovations across the world may help in the development of global fisheries that may drives the sector forward.

Development of appropriate and economically viable technologies is a must to enhance the efficiency of fisheries value chain. In addition to that promotion of entrepreneurship across the fisheries value chain can explore the agribusiness opportunities for the start-ups. ICAR-CIFT, Cochin; since its inception has been working on developing cutting edge technologies in the realm of harvest and post-harvest fisheries catering to the needs and problems in fishing and fish processing in both marine and inland ecosystems. Technologies have been developed for traditional and mechanized harvesting sector to promote sustainable fisheries. Research in post-harvest sector has developed wide range of products like value added foodstuffs from fish and fishery products, nutraceutical and health products from fish, fish waste and other marine resources, proteins and other agro-products from rest raw materials of fish, by products of industries. Business incubation facility in ICAR-CIFT hand holds the prospective entrepreneurs to commercialize the technologies generated at CIFT for wider application across the value chain.

With this backdrop, ICAR-CIFT, Cochin has made an attempt with the help of its innovative technologies to upgrade the knowledge in technologies and management practices of fisheries stakeholders/ professionals across the ITEC partner countries spreading over Asia, Africa, Latin America through this online ITEC training programme on 'Recent advances in harvest and post-harvest technologies in fisheries' (28 Oct.- 10 Nov., 2021). This compendium of lectures delineates the concepts, issues, reviews and relevant technologies related to harvest and post-harvest domain in fisheries highlighting the business opportunities, social issues involved in the sector. I hope this publication must have dealt in detail on the advancements in harvest and post-harvest fisheries keeping eye on the international issues. I am confident that this e-Training Manual will be useful for academicians, researchers, entrepreneurs, policy-makers and planners as well as development practitioners to formulate appropriate strategies with respect to value chain development in fisheries and related sectors.

I specially express my gratitude to ITEC, Ministry of External Affairs, Govt. of India for giving the opportunity to ICAR-CIFT, Cochin as a Knowledge Centre for imparting training to professionals in ITEC countries thus contributing towards strengthening the India's technical collaboration with ITEC partner countries. I appreciate the enthusiasm of the participants to join this programme on digital platform and making the sessions very much interactive throughout. My heartfelt thanks to all the resource scientists, Course Coordinators and Course Directors for their tireless effort and intellectual endeavour to bring out this valuable e-Training Manual.

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1. Mariculture in India

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Introduction

Given the present stagnation in capture fisheries production (3.56 million tonnes in 2019; 3.49 million tonnes in 2018; 3.83 million tonnes in 2017; 3.63 million tonnes in 2016), the sea could be profitably used for mariculture by adopting sustainable and socially-acceptable methodologies. Mariculture is an activity involving cultivation of marine organisms both plants and animals or microbes for food production or other purposes like use in medicine, or nutraceuticals, or any bioactive compounds. Marine organisms like finfishes, shellfishes, seaweeds, microorganisms etc. are cultured in confined systems like coastal ponds, raceways, recirculating systems or in open water cages or pens in seawater systems. With the increasing population and demand for seafood as a healthy diet as well as nutritional supplement, supply has to be considerably increased in the country.

Status of Mariculture in India

India has a coastline of 8128 Km, EEZ of 2.37 million sq. km, continental shelf of about 60 million hectares and brackishwater area of about 1.7 million hectares. The east and west coast of India are productive and are suitable for undertaking mariculture, while the edges of the seas offer scope for large scale culture of organisms such as oysters, mussels and seaweeds. Fish production in India is almost entirely from the capture of fisheries, despite the country having huge potential for sea farming. Vast potential areas remain unutilized and such areas can be designated for establishment of sustainable mariculture as in other South Asian and Southeast Asian countries to enhance seafood production in India. This would enable rural development, employment generation, alternate livelihood and empowerment of weaker sections and women in the country. Unlike other South Asian countries, sea farming or mariculture in India has long been confined to culture of seaweeds, pearl oysters, edible oysters and mussels in a few patches of the South West coast. The main groups of marine resources farmed in India are crustaceans, finfishes, molluscs and seaweeds. Mariculture can partially fulfil the deficit in fish production.

It is estimated that effective utilisation of at least one per cent of this vast resource could achieve an annual production of more than 30 lakh tonnes of fish from mariculture. The open seas could be used for suspending rafts and cages for the culture of finfish and shellfish. Despite the huge potentials, the development of mariculture in India has been rather confined to coastal shrimp culture in the maritime states. Presently, over 0.15 million ha area is under shrimp farming in various coastal states, out of which as much as 0.05 million ha is still adopting traditional practices. There are about 350 hatcheries in India with a built-in capacity of 14 billion seed per annum to supply quality seeds of both marine and freshwater prawns.

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Another vital sector for the sustainable development of mariculture is the feed and feed inputs. Over 30 domestic feed mills are supplying shrimp feed to the farmers, apart from the imported brands.

Species suitable for mariculture

Finfishes

In India the major farmed species include Asian seabass *Lates calcarifer*, cobia *Rachycentron canadum*, pompano *Trachinotus blochii* and *T. mookalee*, orange spotted grouper *Epinephelus coioides*, giant trevally *Caranx ignobilis* and mangrove red snapper *Lutjanus argentimaculatus*. The other farmed species are locally important species like grey mullet *Mugil cephalus,* milk fish *Chanos chanos and* pearl spot *Etroplus suratensis*.

Crustaceans

The farmed crustaceans in India are mainly shrimps black tiger shrimp *Penaeus monodon*, Indian white shrimp *Fenneropenaeus indicus*, Pacific white shrimp *Litopenaeus vannamei* and green shrimp *Penaeus semisulcatus*; lobsters farmed include spiny lobster *Panulirus homarus and P. polyphagus*. Shrimps are farmed in coastal ponds while lobsters in cages of different types and dimensions. Among crabs, the farmed ones include mud crab *Scylla tranquebarica* and the blue swimmer crab *Portunus pelagicus.*

Molluscs

Farmed molluscs are green mussel *Perna viridis* and edible oyster *Crassostrea madrasensis*. Molluscs are farmed in rafts, ropes, or attached to cages, or directly on (or within) the intertidal substrate. Shellfish mariculture does not require feed or fertilizer inputs, nor insecticides or antibiotics, making shellfish aquaculture (or 'mariculture') a self-supporting system.

Seaweeds

Seaweeds are marine plants with a wide variety of species. The vast resources of natural and cultivated seaweeds can provide bioactive substances rich in varieties and large in quantities, which are being increasingly explored in the health industry, using their novel bioactivities. Large amounts of seaweed-derived biological products based on the bioactive seaweed substances have been widely applied in our daily life. Functional foods containing various types of bioactive seaweed substances are expected to grow both in size and significance to help prevent the occurrence and cure the diseases of people in modern society. However, unlike in other Asian countries seaweeds are not consumed in India. The only species cultured in India is the exotic one *Kappaphycus alvarezii*, which is used for extraction of carrageenan. Other local species that has potential in farming are *Gracilaria edulis, G. corticacta and G. dura*.

Marine Ornamentals

For about 14 marine ornamental fish species, seed production technology has been developed by CMFRI and some self- help groups are involved in commercial growing of such ornamentals.

Farming Systems

Sea cage farming

Raising marine organisms under controlled conditions in exposed, sea environments, is a relatively new approach to mariculture in India. When land availability become scarce, sea cage farming will prove to be an opportunity to fish farmers. Diversification of culture practices and inclusion of new candidate species for mariculture will definitely augment fish production. Central Marine Fisheries Research Institute (CMFRI) has also taken steps to develop a bio-secure brood bank for high-value finfish breeding and seed production programmes. Open sea cage culture has been initiated in 2007 in the country and we use indigenous technology for sea cage farming. The cage frame, nets, mooring system etc. are designed indigenously by CMFRI with engineering support from IIT, Kharagpur, India.

Seawater ponds

Coastal mariculture is pond based, which receive water from the sea. Fishes like pompano, grouper and Asian Sea Bass are farmed in coastal ponds in India.

Recirculating Aquaculture Systems (RAS)

RAS is a new concept in Mariculture in India. Currently RAS is used for broodstock maintenance and spawning. Re-circulating systems require high technological development and capital investment, making the use of such technology difficult for many species and countries. However, future development of mariculture must focus in this direction in order to minimize impacts of mariculture on environment. This is particularly true for the production of fin fish and crustaceans.

Integrated multi-trophic aquaculture (IMTA)

In IMTA the fed species like finfishes and shrimps are integrated, in the right proportions, with species which are suspension feeders, deposit feeders or herbivorous fish and species which are extractive(e.g. seaweeds). The wastes generated from one species are recycled to become inputs for another as fertilizers, feed and energy in IMTA. It aims for an ecosystem management that considers site specifications, operational limitations, food safety guidelines and regulations. The goals include environmental sustainability through biomitigation, social acceptability through economic stability and product diversification, reduction of risks, and better management practices. Multi-trophic implies incorporation of species from different trophic or nutritional levels in the same system (Chopin and Robinson, 2004; Chopin, 2006). It involves intensive cultivation of different species in proximity of each other, connected by nutrient and energy transfer through water by a balance of the biological and chemical processes. This balance is achieved by selection of appropriate species in the right proportions to meet with the different ecosystem functions. A successful IMTA should result in better production from the farming system, based on mutual benefits to the co-cultured species and improved ecosystem health, even if the individual production of some of the species is lower compared to what could be reached in monoculture practices over a short-term period (Neori *et al*., 2004). Variations in IMTA include integrated agriculture aquaculture systems (IAAS), integrated sylviculture (mangrove) aquaculture systems (ISiAS), integrated green water aquaculture systems (IGWAS), integrated peri-urban aquaculture systems (IPUAS), integrated fisheries aquaculture systems (IFAS), sustainable ecological aquaculture systems (SEAS), integrated temporal aquaculture systems (ITAS), and integrated sequential aquaculture systems (ISAS), also called partitioned aquaculture systems, or fractionated aquaculture systems (Chopin, 2006). In India, the scope of IMTA is very high because of the diversity available in species that can be farmed, the tropical climate prevalent which is conducive for farming both fed and non-fed species and the increasing demand for a variety of farmed species for domestic consumption as well as export. In any variety of the IMTA systems, the co-cultured species should be more than just biofilters and should be of commercial value (including in terms of biodiversity). Finfishes like cobia *Rachycentron canadum*, Asian seabass *Lates calcarifer*, Orange spotted grouper *Epinephelous coioides* etc. for which hatchery technology of seed production available in India, are the major maricultured species in India. Capture based mariculture of mangrove snapper *Lutjanus argentimaculatus* and giant trevally *Caranx ignobilis* are is also practiced in several pockets of the Indian coast. Non- fed bivalve species like green mussel *Perna viridis* and edible oyster *Crassostrea madrasensis* are also farmed to a greater extent in the country. Extractive species farmed are some red and brown sea weeds like *Gracilaria edulis* and *Kappaphycus alvarezii* are having good market demand for non-edible purposes. However, IMTA is not being practiced in a commercial scale in India. Since mariculture is considered as the future of Indian seafood industry, IMTA has greater scope and prospects. Once the mariculture policy is implemented, the strategy should be more towards enhanced production in a sustainable manner based on lessons learnt in other countries where mariculture has come to a standstill due to many reasons including eutrophication leading to pollution, diseases and parasites and loss of suitable sites. If IMTA is taken as the new and innovative approach for mariculture in India, it is expected to revolutionize production in a sustainable manner in the country.

Enhanced stocking/ sea ranching

Sea ranching involves hatchery production of specific species and release of the juveniles to the natural systems to enhance wild population of that species. The fishermen are mostly benefitted by this system. Sea ranching is being done in India for marine shrimp *Penaeus semisulcatus.*

Role of Mariculture in India

With funding support from government of India production and supply of seed of high value species like cobia, pompano, grouper etc. being carried out in India. CMFRI is the technology hub for most of the activities. Mariculture also aims at empowerment of women and weaker sections of the society. The CMFRI has identified certain sites based on scientific research in all the coastal districts of the state to develop mariculture. GIS platform has been used for the purpose.

Schemes for Mariculture in India

Schemes in mariculture were formulated with the objective to supplement the marine fish production by production of finfish seed by diversification of shrimp hatcheries, sea cage culture, diversified mariculture through molluscan farming and popularization of concept of the cage culture through setting of model and demonstration and units and imparting training to the traditional fishermen and farmers.

The National Fisheries Development Board (NFDB), Hyderabad, is the nodal agency assisting in the fulfilment of the objectives through farmers and entrepreneurs in the country. A subsidy scheme of 40 to 60% project cost is disbursed to the beneficiaries.

2. Trends and Prospects of Inland Fisheries

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Introduction

Inland fisheries are any activity conducted to extract fish and other aquatic organisms from "inland waters". The term "inland waters" is used to refer to lakes, rivers, streams, ponds, inland canals, dams, and other land-locked (usually freshwater) waters (FAO, 2014). While most inland waters are freshwater, there are many areas that are classified nationally as inland waters which have daily or seasonal fluctuations in salinity (e.g. estuaries, deltas, some coastal lagoons). Fisheries in inland waters have long provided an important source of food for mankind. Inland fisheries are critical for a group of developing countries in the world, providing an important source of nutrition and income. Inland fisheries serve important economic, cultural, and recreational roles and play a major role in sustainable ecosystem function throughout the world (Lynch *et al.*, 2015). More than 60 million people in the developing world work with various aspects of inland fisheries and women represent more than half of this workforce. 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. Despite being 'low-tech,' and inexpensive, these fishing techniques are highly effective at catching large amounts of fish and are used extensively in inland fisheries around the globe (Welcomme *et al.*, 2010). Inland fisheries are predominantly small-scale in nature, but large-scale and commercial inland fisheries do make a contribution to livelihoods and food security. In many developed countries, and increasingly in developing countries, inland fisheries support recreational fisheries which enjoy high levels of public participation and contribute to local, regional, and national economic prosperity and human well-being.

Present status of inland fisheries

Global inland fish production reached 63.3 million tonnes in 2018 as per FAO 2020 (Table 1). The trend in global-aggregated catch indicates that inland fisheries catch has risen more or less linearly over the past 20 years increasing by 222,000 tonnes, or 2.3 per cent, per year (1996–2016; FAO FishStatJ, 2018). Inland capture fisheries production was 12 million tonnes accounting 12.5 % of world capture fish production. Inland aquaculture production was 51.3 million tonnes.

Table 1: Global inland fish production

Production type	**1986-1995**	**1996-2005**	**2006-2015**	**2016**	**2017**	**2018**
	Average per year (million tonnes, live weight					

[1] Scientist, Fishing Technology Division, ICAR-CIFT, Kochi-29

Inland (Capture+ Aquaculture)	15.0	28.1	47.4	59.4	61.5	63.3

However, this continuously rising trend in inland fisheries production may be misleading, as the increase in catches can partially be attributed to improved reporting and assessment at the country level rather than entirely due to increased production. Many of the data collection systems for inland waters are unreliable, or in some cases non-existent, while improvements in reporting may also mask trends in individual countries. Inland water catches are more concentrated than marine catches, both geographically and by country. Sixteen countries produced more than 80 percent of the total inland catch, with Asia accounting for two-thirds of global inland production since the mid-2000s. China leads in inland fish production followed by India .

Four major species groups account for about 85 percent of total inland water catches. The first group “carps, barbels and other cyprinids” has shown a continuous increase, rising from about 0.6 million tonnes per year in the mid-2000s to over 1.8 million tonnes in 2018, and explains most of the increase in catches from inland waters in recent years. Catches of the second-largest group “tilapias and other cichlids” have remained stable at between 0.7 million tonnes and 0.85 million tonnes per year, while catches of freshwater crustaceans and freshwater molluscs have also remained relatively stable from about 0.4 million tonnes to 0.45 million.

Inland capture fisheries

Inland capture fisheries play important role in the global challenge to sustainably feed the growing population, as they deliver quality nutrition to some of the world’s most vulnerable populations in a manner that is both accessible and affordable. Catches from inland capture fisheries were at their highest ever in 2018 at 12.0 million tons. Global catches in inland capture fisheries have increased steadily year on year, reaching over 12 million tonnes in 2018. **Table 2: Inland capture fisheries production, by region**

Region	Production (average/ year)			Production				% of total 2018
	1980s	1990s	2000s	2015	2016	2017	2018	
	(million tonnes, live weight)							
Asia	2.87	4.17	5.98	7.30	7.44	7.90	7.95	66
Africa	1.47	1.89	2.34	2.84	2.87	3.00	3.00	25
Americas	0.56	0.54	0.58	0.57	0.60	0.58	0.63	05
Europe	0.28	0.43	0.36	0.43	0.44	0.41	0.41	3
Oceania	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0
Others [1]	0.51	-	-	-	-	-	-	0
World total	5.70	7.05	9.27	11.15	11.37	11.91	12.02	100

[1] Includes the Union of Soviet Socialist Republics. Source: FAO, 2020

Share of inland waters in the total for global captures increased from 8.0 % in late 1990s to 12% in 2018. The apparent low proportion of fish provided by inland capture fisheries globally can be misleading and most likely does not reflect adequately the importance of inland capture fisheries in today's society. Major share of capture fisheries came from Asian (66%) region followed by Africa (25%) (Table 2). Inland water catches have been relatively stable in China, the top producer, averaging about 2.1 million tonnes per year over the last 20 years. The increase in total inland water catches has largely been driven by a number of other major producing countries – notably, India, Bangladesh, Myanmar and Cambodia (Table 3).

Table 3: Inland capture fisheries: Major producing countries

Sl. No.	Country	Production (average/ year)			Production				% of total 2018
		1980s	1990s	2000s	2015	2016	2017	2018	
		(million tonnes, live weight)							
1.	China	0.54	1.46	2.11	1.99	2.00	2.18	1.96	16
2.	India	0.50	0.58	0.84	1.35	1.46	1.59	1.70	14
3.	Bangladesh	0.44	0.50	0.86	1.02	1.05	1.16	1.22	10
4.	Myanmar	0.14	0.15	0.48	0.86	0.89	0.89	0.89	7
5.	Cambodia	0.05	0.09	0.34	0.49	0.51	0.53	0.54	4
Source: FAO, 2020									

Inland aquaculture

Inland aquaculture produces most farmed aquatic animals, mainly in freshwater. Inland aquaculture produced 51.3 million tonnes of aquatic animals, accounting for 62.5 percent of the world's farmed food fish production in 2018, as compared with 57.9 percent in 2000 (Table 4). The farming of aquatic animals in 2018 was dominated by finfish, however dominant position of finfish was gradually reduced from 97.2 percent in 2000 to 91.5 percent (47 million tonnes) in 2018, reflecting the strong growth of other species groups, particularly crustacean farming in freshwater in Asia, including shrimps, crayfish and crabs.

Despite the great diversity in the species raised, aquaculture production by volume is dominated by a small number of "staple" species or species groups at the national, regional and global levels. Finfish farming include 27 species and species groups, which accounted for over 90 percent of total finfish production in 2018 of which the top 7 species together contributed to around 50% (FAO,2020). They are Grass carp, *Ctenopharyngodon idella*, Silver carp, *Hypophthalmichthys molitrix*, Nile tilapia, *Oreochromis niloticus*, Common carp, *Cyprinus carpio*, Bighead carp, *Hypophthalmichthys nobilis*, Catla, *Catla catla* and *Carassius* spp. Compared with finfish, fewer species of crustaceans, molluscs and other aquatic animals are farmed. Inland aquaculture of finfish production is dominated by developing countries such as

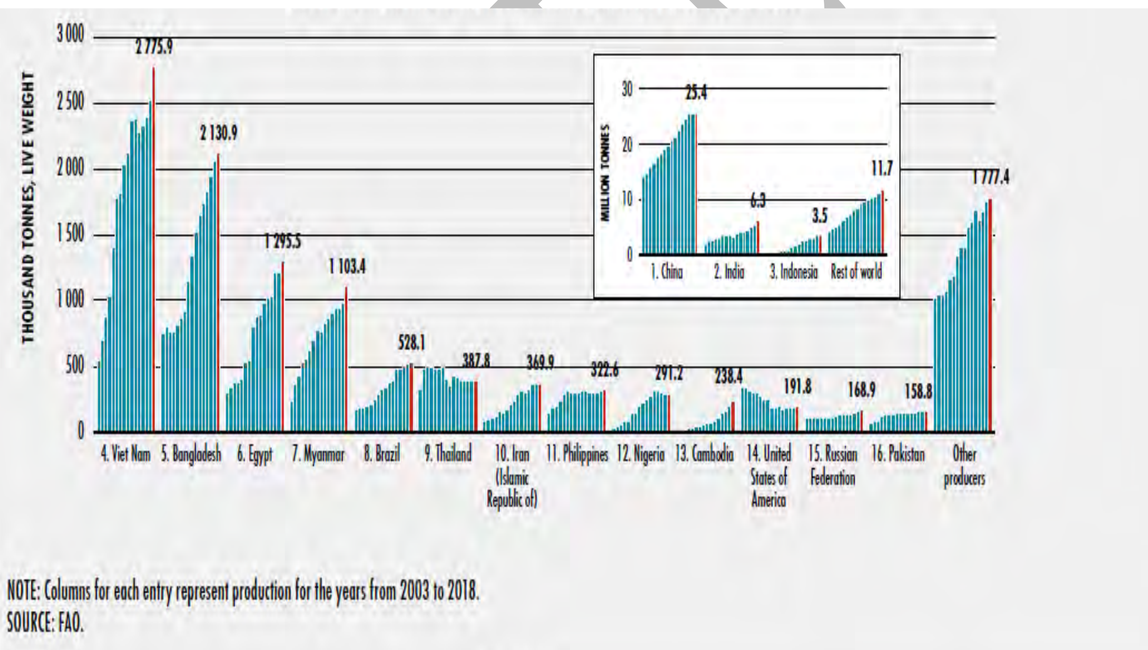
China, India and Indonesia (Figure 1).

Table 4: Aquaculture production of main species groups

Category	Africa	Americas	Asia (– Cyprus)	Europe (+ Cyprus)	Oceania	World
	(thousand tonnes, live weight)					
Inland aquaculture						
1. Finfish	1 893	1 139	43 406	508	5	46 951
2. Crustacea	0	73	3 579	0	0	3 653
3. Molluscs	...	...	207	...	...	207
4. Other aquatic animals	...	1	528	0	...	528
Subtotal	*1 893*	*1 213*	*47 719*	*508*	*6*	*51 339*

(Source: FAO, 2020)

Figure 1: World Inland aquaculture finfish production by major producers



Challenges in inland fisheries development

Freshwater species and habitats are some of the most threatened in the world with an estimated one fifth of the described freshwater fish species are extinct, threatened or endangered. Inland fish species face higher declines relative to marine and are disproportionally understudied. Inland fisheries are subjected to a suite of anthropogenic stressors across aquatic-terrestrial landscapes. Numerous challenges and threats are hampering the production and health of inland fisheries.

Improper representation of inland fisheries data

The major issue associated with inland fisheries development are the under estimation of inland fisheries data. The lack of routine monitoring across a wide range of inland fisheries constrains the ability to provide an indication of the status or health of global inland fisheries. This limitation covers both the effect of fishing activity, as well as that arising from anthropogenic drivers (including climate variability). Recent developments in the statistical coverage may have contributed to the rapid increase in reported landings particularly since the mid2000s (FAO 2012), however the production in many waters may still be grossly underestimated. The underlying reasons for the improper representation of inland catches are as follows (Table 5)

Table 5: Reasons for inland fisheries receiving less official attention

Main reason	Underlying reasons
Inland fisheries catches are often hidden or "invisible"	Inland capture fisheries landings tend to be low volume and widely dispersed
	No centralized landing site, fishes sold locally or consumed by households
	Catch rarely recorded and production often underestimated
	Fisheries in smaller tributaries and waterbodies are generally overlooked
Governments do not consider inland fisheries important contributors to food security, GDP and livelihoods.	Monitoring mostly for commercial fisheries
	Lack of monitoring/recording of fishing activities in river tributaries, minor waterbodies, small streams, floodplains
	The costs of monitoring small-scale fisheries are not returned in revenues to the state

Habitat loss

The status of marine fisheries is mainly influenced by fishing pressure wheras the status of inland fisheries depends heavily upon the quantity and quality of freshwater and diversity of fish habitats—all of which are predominantly influenced by factors external to the fisheries. Both natural and anthropogenic environmental drivers affect aquatic habitats, water flows, habitat connectivity and water quality. About 10% of the world's freshwaters are abstracted annually for human use. Loss of wild habitat and water flows because of changes in rivers, wetlands and waterbodies caused by changing land use, watershed development and drainage of freshwater wetlands, reduces the available habitat to sustain populations. Physical obstruction and changing water flow regimes impacts upstream and downstream migration and reproduction of riverine species caused by damming of rivers and loss of connectivity in waterways.

Pollution

Pollution have caused substantial decline or change in inland fishery resources. Direct effect include discharge of toxins and heavy metals from untreated industrial discharges leading to fish kills. Indirect effect of effluents from urbanization leads to eutrophication and water quality changes and food chain disruptions. Pesticide runoff from agriculture directly affects fish, or indirectly through ecosystem level impact on prey/food chains.

Overfishing

In spite of the trend of gradually increasing inland catches in the global scale, there has been a reduction in the catches of certain species, apparently due to reduction in population sizes (FAO 2010). The decline may have been partly masked by the recent improvements in catch data collection and aggregation of catches, and because the total number of fishers may still be increasing. Excess fishing pressure can change the community composition of inland ecosystems by removing the larger, slower growing species (fishing down the food web). Fishing also exerts a selective pressure on target species, e.g. early maturity and small size at age of first maturity, as well as on non-target species through by-catch and discards.

Non-native species

Introduction of non-native species can increase production and value of inland ecosystems, but they can also have a profound and devastating impact upon an ecosystem such as serious effects on natural habitats and wild fish stock. Negative impacts include reduced biodiversity because of predation, competition and habitat alteration. In many lakes and rivers, introduced species are a major threat as their occurrence may change the fish community structure and nutrient cycle. Also leads to spreading of disease and parsites to other native species.

Climate change

Inland fisheries are highly vulnerable to the impacts of climate variability. Inland biodiversity is often confined to specific river basins or streams and therefore cannot migrate as marine species when habitat starts to degrade. Negative impacts include reduced numbers and range of populations because of habitat degradation, e.g. temperature increase and acidification. For aquaculture, although the sector is expected to continue growing to meet the world's demand for aquatic food, climate change could result in favourable, unfavourable or neutral changes, with negative impacts likely to predominate in developing countries as a result of a decreased productivity due to suboptimal farming conditions and other perturbations.

Measures for responsible inland fisheries

Human population is expected to exceed 9 billion by 2050 and the growing populations will call for significant increases in food production at an affordable price. The need for animal protein, including fish, will increase dramatically. Because most marine fish stocks are already fully exploited or overexploited, it is assumed that fishing pressure on inland fish stocks will rise. The role of inland fisheries in meeting challenges faced by individuals, society, and the environment is often underappreciated or ignored despite its importance (Lynch *et al*., 2016). Inland fisheries can be a significant contributor to poverty alleviation and prevention of poverty escalation, where they are a primary livelihood, a secondary livelihood, or even as a subsistence source of nutrition. The following steps will be a path towards responsible use of inland resources for optimally managing the resources so that they can play a significant role in providing food security, income generation and sustaining economic growth for the future generations.

Improve the assessment of inland fishery

Develop, promote and support standardized methods for the assessment of inland fisheries harvest and aquaculture production including: data collection methods, besides the traditional catch and effort surveys, such as population census, consumption studies, market surveys and habitat classification. Also, a minimum set of data requirements that would be practical for countries to collect can be established which would allow cross-sectoral comparisons. In addition to that, increase support for efforts to improve capacity of fishery resource officers to collect information on the sector.

Correctly value inland aquatic ecosystem

The true economic and social values of healthy, productive inland aquatic ecosystems are often overlooked, underestimated and not taken into account in decision-making related to land and water use. Promote and support the adoption of approaches that include assessment of the ecosystem services provided by inland aquatic ecosystems to value their contribution to ecosystem health and societal wellbeing.

Promote the nutritional value of inland fisheries

The relative contribution of inland fisheries to food security and nutrition is higher in poor food-insecure regions of the world than in many developed countries that have alternate sources of food. Maintain or improve the accessibility/availability of nutrient-rich fish in areas with traditionally high fish consumption and/or high levels of under-nourishment and malnourishment by ensuring fair and equitable access regimes.

Develop science-based approaches to inland fishery management

Many inland waterbodies do not have fishery or resource management arrangements that can adequately address sustainable use of resources. This may result in excessive fishing pressure, decreased catch per unit effort, and conflicts between fishers, as well as changes in the productivity of fishery resources. Adopting ecosystem approach to fisheries in inland waters will help to achieve the integrated management of land, water and living resources for promoting their conservation and sustainable use in an equitable way. Also support effective governmental, communal/co-operative, or rights-based governance arrangements and improve compliance with fishery management regulations.

Improve communication among freshwater users

Information on the importance of the inland fishery and aquaculture sectors is often not shared with or accessed by policy-makers, stakeholders and the general public, thereby making it difficult to generate political will to protect inland fishery resources and the people that depend on them. Appropriate and accessible communication channels can be used to disseminate information about inland fish, fishers and fisheries to raise awareness of inland fisheries' values and issues, to alter human behaviour, and influence relevant policy and management. The fisheries sector should engage other users of freshwater resources and participate in national and international fora that address freshwater resource issues, conflicts and synergies.

Improve governance, especially for shared waterbodies

Many national, international and transboundary inland waterbodies do not have a governance structure that holistically addresses the use and development of the water and its fishery resources. Establish governance institutions (e.g., river or lake basin authorities) or expand and strengthen the mandate and capacity of existing institutions to address inland fisheries needs in the decision making processes. Legal frameworks for multistakeholder-based decision-making and management can be identified and strengthened.

Make aquaculture an important ally

Aquaculture is the fastest-growing food production sector and an important component in many poverty alleviation and food security programmes. It can complement capture fisheries, e.g., through stocking programmes, by providing alternative livelihoods for fishers leaving the capture fisheries sector, and by providing alternative food resources. However, the use of non-native species in aquaculture development has to be properly managed and regulated.

Develop an action plan for global inland fisheries

In light of the threats and challenges in inland fisheries, there exists a great need for policies to be closely integrated with those of other sectors. Inland action plan based on the above steps will be helpful to ensure the sustainability and responsible use of inland fisheries and aquatic resources for future generations.

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3. Advanced techniques in freshwater farming

Vikas P.A [1]& Shinoj Subramannian[2]

Fish from inland resources contributes 85 per cent of the total fish production in India. The fish production during 2019-20 was 12.3 million MT in the country with an export income of 46,662.82 Crore. India is aiming to increase production to 22 million MT by 2025 and an average annual growth rate of about 8.2 per cent is required to achieve this target. Enhancing productivity, utilizing open and untapped water resources, promoting high density fish farming and promoting fast growing breeds are the different approaches being utilized. The Krishi Vigyan Kendra (KVK) Ernakulam has been working in these lines to achieve higher fish production from inland resources in ernakulam district.

Grass carp (*Ctenopharyngodonidella*), silver carp (*Hypophthalmichthys molitrix*), Tilapia (*Tilapia nilotica*), Common carp (*Cyprinus carpio*), big head carp (*Hypophthalmichthys nobilis*), Shrimp, Crabs, Mullet, Milkfish, Tilapia, Pearlspot, Red snapper, Pompano, Asian Seabass are the popular species for inland fish farming. Natural ponds, open water bodies, artificial tank systems, cages cited in open water bodies *etc.* are the specific inland resources. Species suited to each system is provided in Fig 1.

Fig 1. Species suited to different fish farming systems

Fish farming in natural ponds

Fish farming in natural ponds is an established practice and both fresh water and brackish water

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resources comes under this category. Carps, Tilapia, and Pangasius are the main candidate species cultured in freshwater ponds. Among these most extensively cultivated species are Indian Major Carps (IMC) viz., Catla (Catlacatla), rohu (Labeorohita), and mrigal (Cirrhinusmrigala). Along with IMC, exotic carps such as common carp (Cyprinus carpio), grass carp (Ctenopharyngodonidella) and silver carp (Hypophthalmichthys molitrix) are also farmed.

Subsequent to implementing guidelines for Responsible Farming of Tilapia by NFDB in 2015, there was swift progress in Tilapia farming during the last few years. Farmers are advised to take up Tilapia farming using all-male or sterile improved strains or hybrid seeds for better production. Registration and license from Department of Fisheries are mandatory. The *Genetically Improved Farmed Tilapia (GIFT)* and *Chitralada* are the advanced strains developed through selective breeding. Strains such as Big-nin, Nam-sai, Super-red and Super-black are also available. Since the hatchery technologies of Carps and Tilapia are standardized in a commercial scale, seed availability is assured and hence farming is getting momentum.

Mullet, Milkfish and Pearlspot are the major species being farmed in brackish water. Farming protocols are well established and commercial viability is also proven. Due to lack of enough seeds available commercially, farmers are constrained to depend on wild-caught seeds, availability of which is also getting reduced on account of climate change and developmental works that has considerably affecting Mullet and Milkfish farming.

Fish farming in Artificial tanks

Fish farming in artificial tanks may not be economically viable except in case of high value fish. However, it is a possibility for producing safe to eat fish in limited space in homesteads. Tilapia, Murrell, Pangasius, Vannamei *etc.*, are the candidate species suitable for artificial tanks. There are systems where fish farming is combined with plants by re-circulating water. Plant growing medium act as biological filter to manage toxic compounds in the ponds while the fish faecal matter and waste are effectively utilized for growing plants. Recirculatory Aquaculture System (RAS) use mechanical and biological filters for keeping up the water quality. Biofloc method of fish farming in artificial tanks manages fish faecal matter and feed waste inside the ponds itself. Heterotorphic bacteria utilize carbon sources in wastes for multiplication. External probiotics application is essential to keep the microbes density in the ponds. Managing artificial fish farming system require technical knowhow, precise monitoring, large infrastructure and high operation cost.

Fig.2. Aquaponics unit

Fig 3. RAS unit

Fig 4. Biofloc unit

Fish farming in cages

Cage aquaculture is the method of rearing fish in confined enclosures located in open water resources by administering external feed. Reservoirs, backwaters, sea, Rivers and lakes are potential areas. Asian Seabass, Pearlspot, Red Snapper, Giant Trevally, Tilapia and Pangasius are the species suitable for cage farming. Abandoned granite quarry ponds are ideal location for cage farming.

Fish seed production

Hatchery method of commercial seed production of Indian Major Carps, Pangasius, Anabas, and other fishes is well established across India. There is a well established seed trade network also across the country. Whereas supply of smallest size seeds is preferred by traders to reduce transportation cost, the survival rate of which is low. Hence nursery care is essential before releasing such seeds to farms. The Ernakulam KVK has been training farmers on scientific nursery rearing and fattening to fingerling stage to enhance survival percentage. The KVK has also developed farmer participatory seed fattening units in their fields. Such units are termed as KVK's Satellite seed production centers where KVK provides technology backstopping and quality control so that farmers produce and supply quality seeds.

Pearlspot seed production

Pearl spot is the most popular and premium variety fish in Kerala and is the State fish of Kerala. Pearl spot is heterosexual, monogamous, gonochoristic and perform external fertilization. Economically viable hatchery seed production is not yet established. Low fecundity rate (780 to 3000), less response to induced breeding, lengthy larvae rearing period (90 to 120 days) and high cost of production are the issues. The KVK Ernakulam has established a farmer participatory seed production method where farmers are trained on massive seed production in natural ponds. Pond preparation, brood stock selection, breeding, feeding, seed collection, packing, transportation and marketing are the key skills imparted to farmers. The KVK also assists farmers to market the seeds.

Fig 5. Pearl spot seed production in natural ponds

Fig 6. Pearlspot seeds ready for distribution

Carp seed production

New fast growing fish strains such as Jayanti Rohu and Amur Carp are available in India taht are developed by various research organizations such as ICAR -Central Institute of Freshwater Aquaculture(CIFA), Bhubaneswar and Karnataka Veterinary, Animal and Fisheries Sciences University, Bengaluru. The National Freshwater Fish Brood Bank (NFFBB) has taken up initiatives to scale up the seed production and supply. The KVK Ernakulam has established carp seed fattening units in farmer fields to produce and supply fingerlings by sourcing seeds from above mentioned organizations. The KVK also assists in marketing fingerlings.

Fig 9. Fish seed fattening pond

Fig 10. Jayanti Rohu Spawn packed in oxygen filled bags

Fig 11. Jayanto Rohu fingerlings

Fig 12. KVK’s advertisement on fish seeds

4. Advanced techniques of commercial fishing

A.K. Choudhury[1] and K.B. Bijumon[2]

India is having a coast line of 8,129 km spread across 9 maritime states and 2 union territories namely Lakshadweep and Andaman & Nicobar Islands are located in Arabian sea and Bay of Bengal respectively with 2.02 million sq. km as EEZ and 0.5 million sq. km as continental shelf. According to National Marine Fisheries census 2010, the marine fishermen population in India is estimated at 4.0 million, of which 0.99 million are active fishermen. Among active fishermen, 33% employed in the mechanized sector, 62% in the motorized sector and 5 % in the artisanal sector. In the marine fisheries sector, there are 37.3 % mechanized boats, 36.7 % motorized boats and 26.0 % non – motorized crafts.

With absolute rights on the EEZ, India has also acquired the responsibility to conserve, develop and optimally exploit the marine resources up to 200 nautical miles off our coastline (Planning Commission, 2007). The current exploitation from the marine capture sector is 3.81 million tonnes in 2017 as against the total projected potential of 4.41 million tones (2011 revalidation report, Dept. of AHDF). of which demersal is 2.13 million tons, Neritic pelagic is 2.07 million tons and Oceanic pelagic is 0.22 million tons.

Indian marine fishery harvesting mostly concentrate around coastal waters up to 100 meters depth and about 90 per cent of the catch comes from up to 50 m. A recent revalidation of marine fisheries potential has shown that the fishing pressure on the stock in near shore waters has gone up considerably and signs of over exploitation of species is becoming increasingly evident and further increase in effort in the coastal sector would be detrimental to sustainable yield. The impact of mechanized trawling and purse seining has also caused resource depletion. Sustainable resources exploitation from this sector is still possible through regulatory management strategies and concerted policy efforts for different species and for different regions.

Deep sea fishery over the years has undergone several changes like modernization of fishing practices by including advanced acoustic equipments, navigational and emergency equipments along with diversification, intensification and extension of fishing to new ground which enhanced landing of targeted commercial species along with incidental by catch. Therefore, there is an urgent need for looking forward the unexploited or least exploited resources so as to meet demand towards the nutritional security of the

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country as a whole and for earning foreign money through export promotion. The fishing and allied activities provide employment opportunities for millions and it contribute 1.1 % of the total GDP of India. At this juncture, exploitation of under exploited non-conventional resources from the distant waters of the Indian EEZ is the only solution left with us. Moreover, there is an ample scope for increasing production by venturing into deeper waters of the EEZ, for underexploited and untapped resources and which can be achieved by operating the following resource specific and non-specific fishing gears operations.

Squid jigging

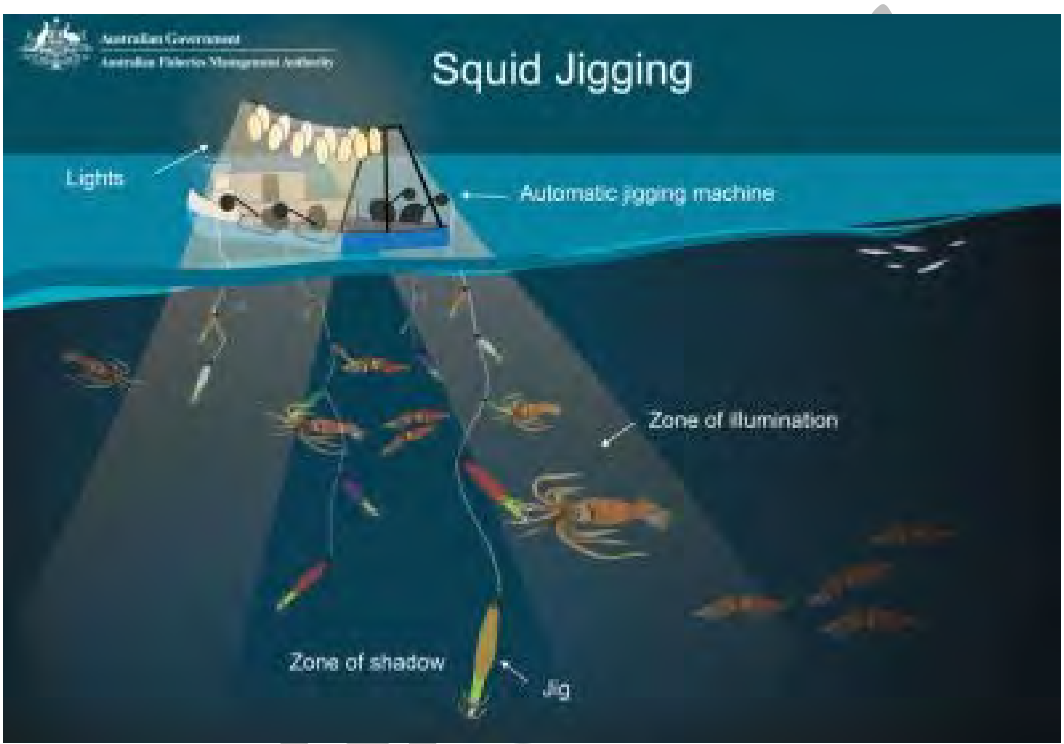
Squid jigging is a mechanical device used for catching squids by using coloured jigs and artificial lights. Both manually operated and automatic jigging machines are available for squid fishing. It consists of a drum where the line is spooled and the roller through which the line is released. The line is jigged or jerked during the operation. This jerky movement of the coloured jigs simulates the prey and the attracted squids are impaled by the rosette of hooks in the moving jigs. The machine is provided with electric motor and line drums are fitted on both sides of motor. Jigs are spindle shaped coloured plastic lures with two rows of small sharp barbless hooks. Different colour like red, orange, green white, blue with a glowing appearance in water used as jigs.

Luring lamps are important in squid fishing. As the squid are easily attracted towards the light. Luring lamp is normally used above the water level. But sometimes underwater luring lamps are also used to induce the squid shoal to come upto the surface.

Squid jigging accounts for nearly 40 per cent of the world cephalopod catches followed by trawling, which contributes 25 per cent of the catch. Gillnets are also used for catching the squids, which accounts for nearly 10 per cent of the catch. Gears like shore seines, boat seines, hooks and lines and spearing are the popular methods to catch cephalopods. Cephalopods are considered as an important source of marine fishery resource and many of the species are exploited as by catch by trawlers along the Indian coast and the fishery forms 4-5 per cent of the total marine fish. Arabian Sea is considered as one of the richest fishing regions for *Sthenoteuthis oualaniensis* (Mohamed, 2012). The preliminary studies on the oceanic squids in the Arabian sea indicated that the area around Lakshadweep Islands is a major spawning grounds for oceanic squids (CMFRI, 2011). These species are known as the masters of the Arabian Seas due to its high abundance and large oceanic squids occupy and monopolise the trophic niche being apex predators in the Arabian Sea.

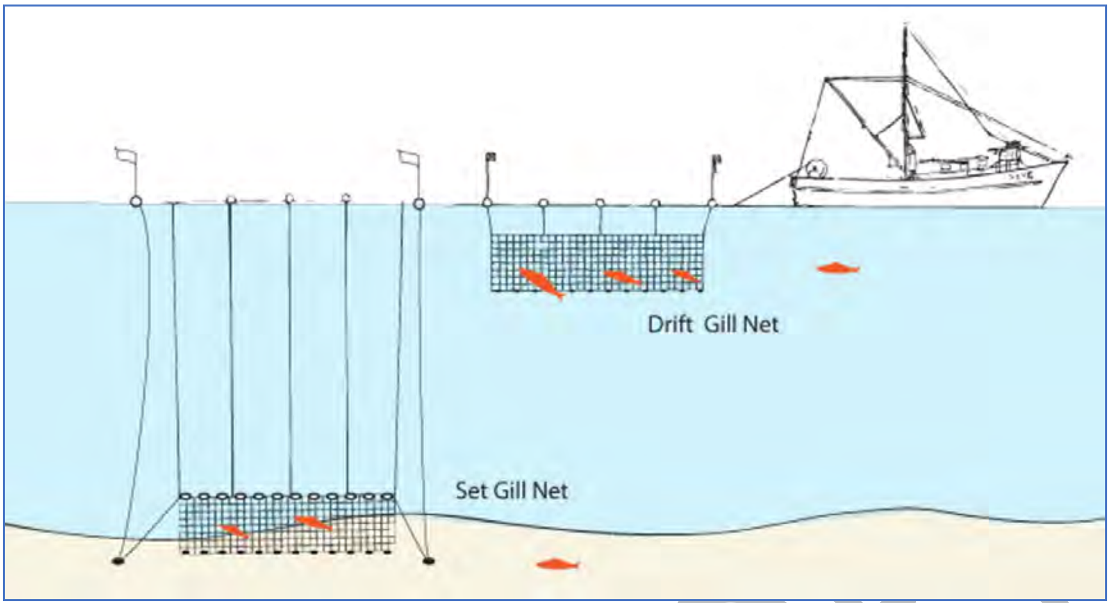
Fish aggregating devices (FADs) are traditionally used by the fishermen to attract and aggregate the species closer to the shore. Fishermen from Karnataka and Kerala started FAD assisted cephalopod fishery in coastal waters.

However, It is indicated that the FAD assisted cephalopod fishery increases the vulnerability of spawners which may affect the conservation part of management measures. The introduction of high opening bottom trawl nets leads to an rapid increase in the cephalopod production from the Indian EEZ (Sundaram and Deshmukh, 2011).



Gill Netting

Gillnet is a large wall of netting which may be set at surface or below the water level or at the bottom or any depth in between surface and bottom according to the availability of resources. Probably the oldest form of net fishing having been in use for the last 1000 years. Fish are caught by gilling as they attempt to pass through the net. The gill nets are mainly used to catch the fish whose body size is almost uniform, since the mesh size must be matched to the fish's girth. This is one of the eco friendly and passive fishing gear which is used safely to catch resources without causing any damage to the ecosystem. It can be used as a small-scale fishery and now it has been modernized by inducting equipments and machineries due to the immense pressure on capture fishery at deeper waters. Salmon, cod Haddock, Pollock, barracuda Herring, Mullet, Rockfish, Sea bass, Shark, Sturgeon Swordfish, Tuna etc are caught by operating the gill nets.

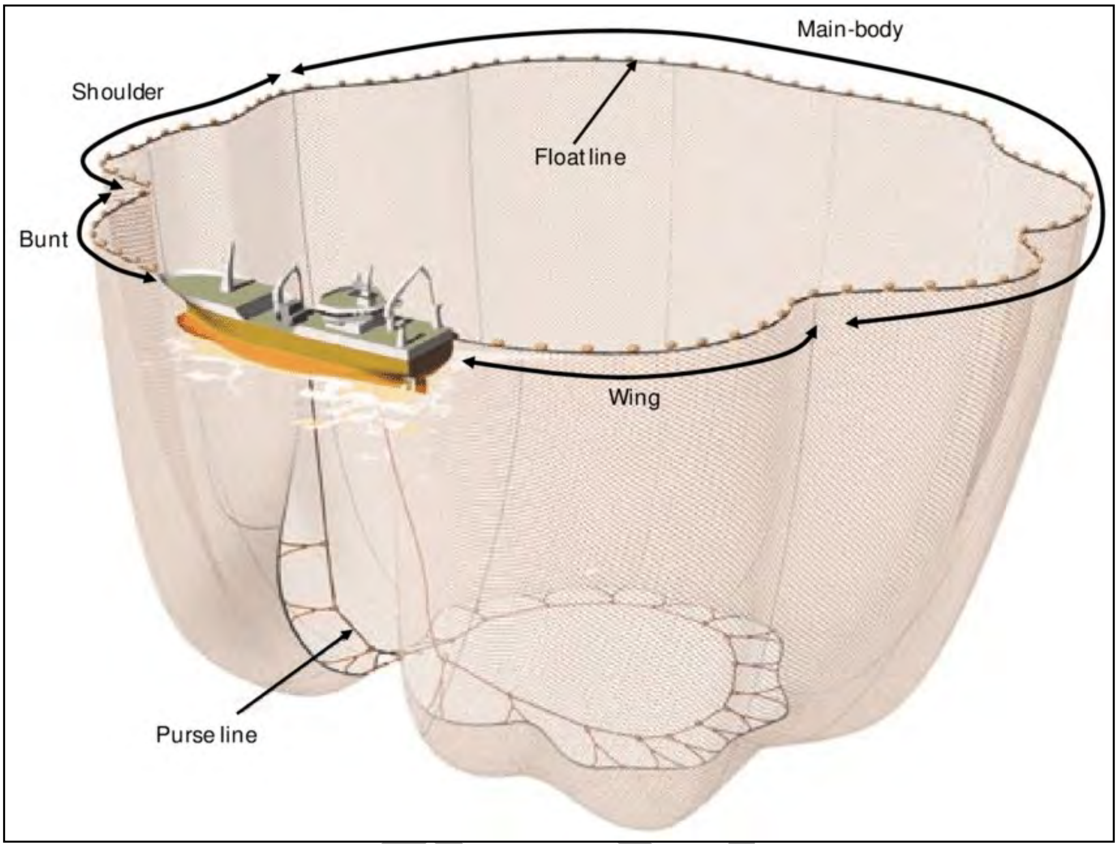


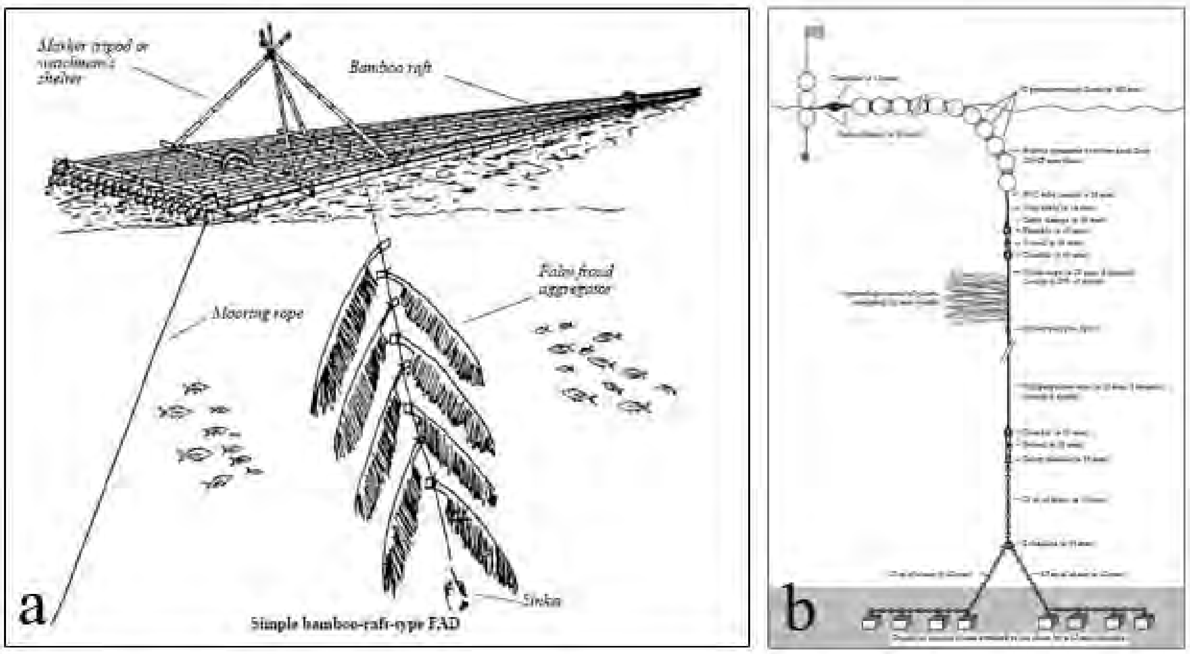
Purse seining

A purse seine is a large wall of netting deployed around an area with school of fish. The seine has floats along the top line and a lead line with sinkers. The purse rings are attached along the foot ropes through bridles. Once, a school of fish is located, the seiner encircles the school with the net. The lead line is then pulled in, and "pursing" the net, closed the bottom, preventing fish from escaping by swimming downward.

Purse seining is one of the most advanced and efficient commercial fishing methods for capturing pelagic shoaling fishes like sardine, mackerel, Tunas etc. Purse seines are also used to catch the demersal fish such as cod by modifying its design to operate close to the bottom. It probably catches the higher percentage of total world fish landings than any other single fishing method. Advances in purse seining was supported by introduction of high tenacity synthetic fibers, improvement in vessel technology, gear handling equipments such as power block, fish aggregating techniques, fish detection devices such a sonar and remote sensing techniques.

Fish luring methods are used to concentrate fish for purse seining. This is a more effective method than chasing and surrounding methods. Fish aggregating devices (FADs) made of various materials used to concentrate the fish in south- East Asian countries. The FADs are fabricated by locally available materials such as coconut palm leaf, coconut husk, Spadix, nettings and used tyres. The fish start aggregating in about 1-2 weeks if the fish is abundant in that area. The FADs are equipped with selective call radio signals only on a





pre-fixed frequency and code which are picked up onboard direction finders to fix the position of FADs. This ensures secrecy of the location of FADs.

During night fishing, powerful lights are arranged onboard a vessel or on the buoy to attract the fishes. When fishes are concentrated around and it is confirmed by acoustic methods, purse seining is carried out and captures the resources. However, the light fishing is banned.

Ring seine of Kerala

Commercial purse seine fishing started during the late seventies in Cochin, Kerala. Subsequently process of motorization also started in eighties. Ring seine was introduced in mid eighties and it became widely adopted as one of the significant fishing methods in marine fishing sector of the state. The original ring seine was called as "Thangu vala" in Malayalam. However, it differed from Purse seine in that it is smaller version with light webbing. Tapered towards wing on the ends and having 3 parts, a central bunt made of thicker twine and two end portions or wings.

Trawl fishing

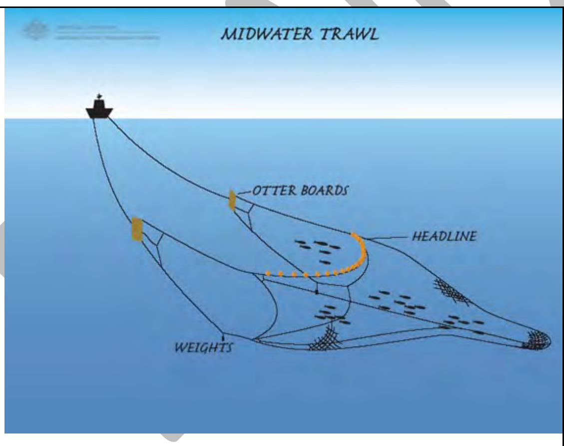
Trawl fishing is one of the important and intensive fishing operation in India which contribute the highest percentage of marine capture fishery. A large conical bag shaped net is dragged by one /two vessels by which an area under water is swept. It is operated at bottom or mid water column or sub surface pelagic area at the fishery resources as indicated by the Echo sounder/ SONAR. The bottom trawl fishing is a destructive fishing operation as it damages the habitat of bottom dwelling organisms. However, it is still contributing as the major fishery.

The Net sounder is an aid for trawl fishing. The knowledge of the position and state of trawl underwater contribute much for a successful fishing operation. This requires necessary sensors or transducers to be positioned on the Net and the receiver installed onboard the ship along with the link medium either by cable or by means of signals. The transducers give inputs regarding trawl opening both horizontal and vertical, vertical depth from the net to the sea bed and sea surface, water temperature, catch details, spreading of the otter board etc. The density of the fish population entering the trawl mouth is an indication of the catch details which is monitored by the sensors at the head rope.

The catch monitoring system is used with a variety of sensors. All these sensors are placed on the trawl at its cod end portion. The effects of currents can reduce the trawling yield. The sensors detect the currents and tides by which the traction speed can be adjusted and the yield is improved.

Aimed trawling requires the matching of vessels course and towing depth with that of particular shoal. The vessel searches for a fish shoal using a SONAR usually mounted towards the bow and which can be extended below the hull and rotated at 360^{o} and can be tilted to search all around the vessel throughout the depth of the water column. Information showing the extend and density of fish shoal within the range is usually displayed on a colour monitor enabling the skipper to aim for an appropriate target and maneuver accordingly.

With the aid of net monitoring system skipper can then adjust warp length and speed to place the net at appropriate depth, and the course as necessary according to the information from the SONAR.



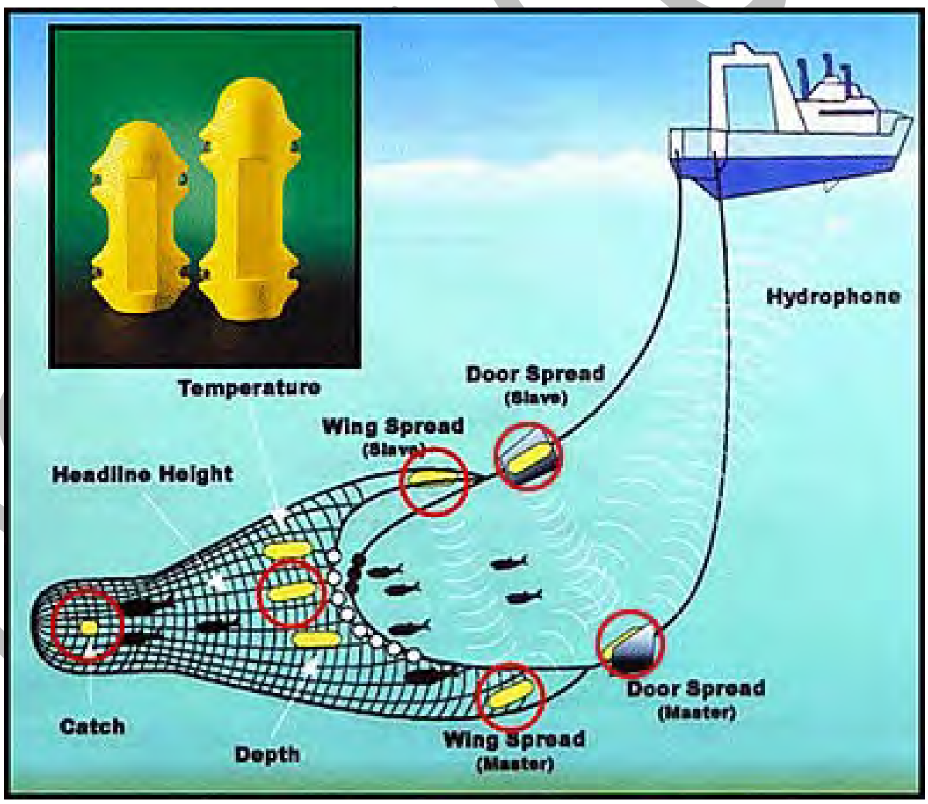
Midwater Trawling

Bottom Trawling

Auto trawling

The latest development integrates and coordinate information from the net monitor, fish finding, and position fixing with the ship's propulsion control system and auto pilot to provide computerized control of the fishing when the skipper has reached in a fishing area and one or more fish shoals are located. He can shoot the gear and set up the automation system. The computer calculates the probability of catching from each school and if the skipper decides to fish a particular school, he then pushes a button and computer takes over the entire operation.

The system determines the course and distance to the school, together with its depth, density of fish and indicates the time needed to reach it . Necessary course changes will be made with speed of vessel and warp length adjustment as necessary on the information of the shoal. If the school diverse, speed is reduced and more warp paid out to lower the trawl. The computer is continuously updated for shift in position of the school as well as the net behavior due to underwater current and the operation continues until the net sensors indicates that net is completely dragged over the shoal and the entire fish is in the codend. If a rock pinnacle or other sea bed obstruction is detected on the Echosounder, the net is automatically lifted above the obstruction before resuming fishing.

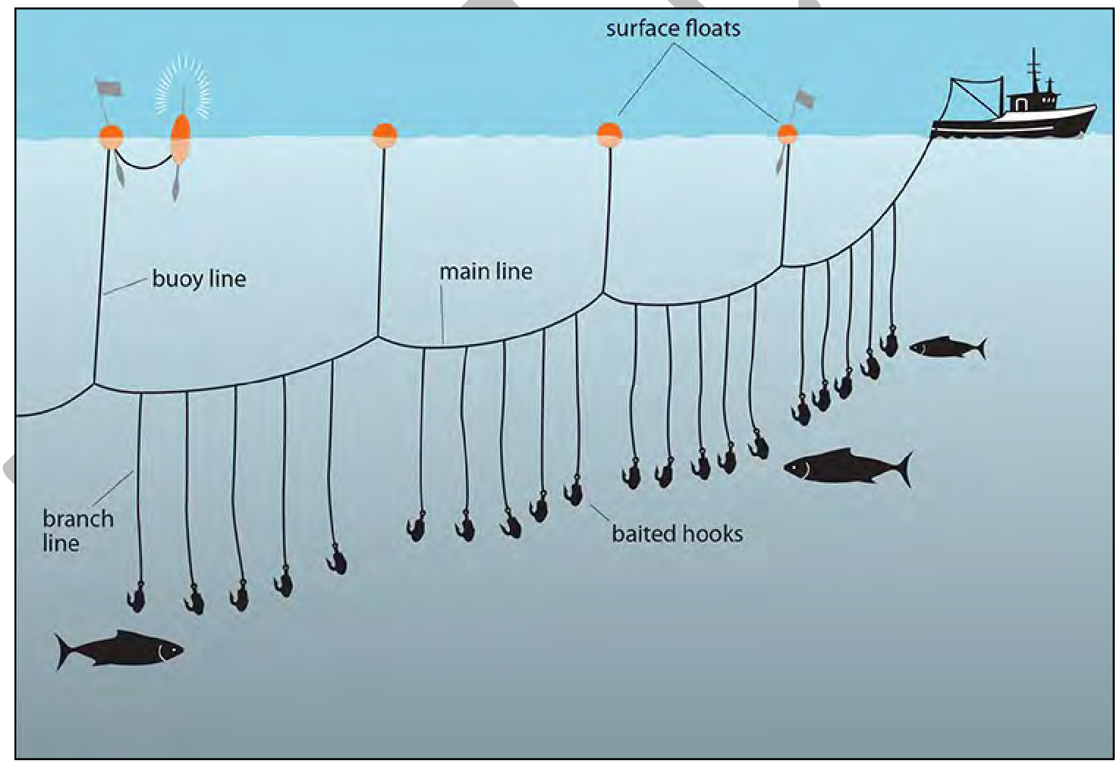


Tuna long line

Long line fishing for Tuna in high seas is a very popular technique employed all over the world. The gear consists of Main line, Branch line, hooks, float line, radio buoy, radar reflector, Flag buoys and other accessories. For operational convenience and easy handling, the gear is divided into units called “Baskets” and each basket consists of a main line, branch line with hooks and float line with floats. Generally, a traditional Japanese multifilament long line consists of five branch line in a basket. However, monofilament long line consists of 5 to10 branch line in a basket. It is an efficient and recommended fishing operation for harvesting targeted tunas and bill fishes and sharks as the bycatch. Specially designed long line is operated for capturing Sharks.

Automated long line system consists of a line hauler with a mechanized method of cleaning the hooks and untangling branch lines from the main line. In some systems branch lines are separated and stored on racks or magazines and the main line is wound and stored on a drum. In other systems, main line with branch lines are stored on the drum. While setting , the hooks are baited by drawing through an automatic baiting machine.

However, oceanic skipjack tuna is captured by purse seining and pole and line fishing in Lakshadweep islands. The automated shooting and hauling the line including baiting are the advancements in long line fishing. In modern large-scale operations, main line is continuous and stored in a main line storage tank or on a powered reel.

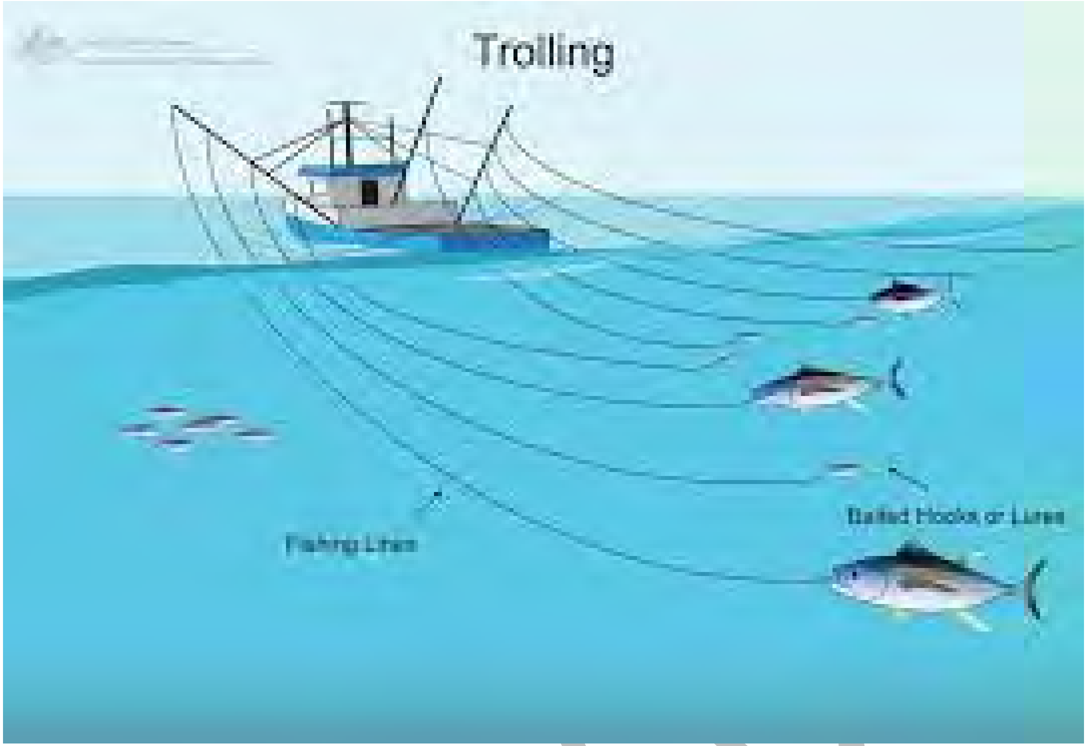


Pole and Line Fishing.

It is a traditional fishing for skipjack tuna in Lakshadweep Island, the union territory of India. It is an effective method for capturing the shoaling pelagic skipjack tuna. When the vessel approaches as near as the shoal, live baits are thrown out (chumming) towards the shoal to attract the shoal of fish towards the boat. As soon as the fish come and concentrate near the vessel, chumming is increased. If the tuna reacts well, the engine is stopped. Simultaneously, water spraying is started on the sea surface through nozzle arranged along the fore and sides/stern of the vessel using pumps. When the fish's swims around the vessel, it is considered that they are fully attracted and the process of spraying continues so as to keep the fish in the vicinity of the vessel. Then the crew onboard put the barbless hook into the water and make a jerk and pull and bring the fish onboard. With another jerk the fish unhook on the deck.

Trolling

Fishing with troll lines, baited with artificial lures popularly known as trolling is an effective and important gear for the capture of pelagic predatory fishes like seer fish. skipjack, bonito, barracuda etc. This gear can be operated from small mechanized boats as well as from small sailing vessels. Two or three bamboo poles are required for the operation of this gear. These poles must be very strong and 8 to 11 m in length. These poles should be fixed in the deck so as to provide maximum spread to the lines. Poly amide lines of 3 mm dia are generally used as main line. The length of line must be 40 to 50 m. haul in lines are used to facilitate hauling of the main line. Different types of depressors are widely used in trolling. These are used to take the lines at different depth below the surface water.


Trolling
Baited Hooks or Lures
Fishing Lines

5. Recent trends in passive fishing techniques

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Fishing is a primitive practice dating back to pre-historic times. Initially humans caught fishes by bear hands, or by using pointed wooden poles or sharp bones. Slowly implements and tools were developed to catch fish in a better way. Later, as civilization advanced and with industrialization, sophisticated technologies and gadgets were developed and fishing changed from mere sustenance level to a commercial level. Besides giving food and livelihood, fishing is also carried out as a means of recreation in modern times.

Physical and mechanical tools and devices used to catch fish are collectively called as fishing gears. Fishing can also be carried out without using any device or implements. In fact, even now fish are caught using barefoot and hands. There are different mechanisms or processes of fish capture. It can be filtering, hooking, gilling and tangling, trapping, spearing or pumping. Depending on the mechanism of capture process, fishing gears differ in design, structure, mode of operation, target species and area of operation.
Fishing gears are classified into active and passive gears based on principle of capture, design and mode of operation. The basic difference between active and passive gears is that in active gears, the gear moves towards the fish and catch whereas in passive fishing gears, the gear stands stationary and the fish moves towards the gear and get caught. Trawls & dredges, surrounding nets & seines and actively operated hook & lines (Troll lines, Jiggs and Pole & line) are the main active gears. Of these, trawls and surrounding nets are the major gears used for industrial fishing.

Passive fishing gears

Passive gears are stationary or immobile gears which need not be moved viz., towed, dragged, pushed or pulled to catch fish. Passive gears are a distinct group of artisanal or traditional gears such as gill nets & entangling nets, hook and lines, traps & pots, wires, set bag nets etc.

Advantages:

In the context of high cost of energy, passive gears are important as they are low-energy gears. Besides, these gears need low investment, are simple in design, construction and operation, and are relatively less detrimental to the ecosystem compared to active gears. Passive fishing gears can be operated without special skills and they do not need sophisticated and rarely require sophisticated technology and/ equipment except a vessel and that can be a non-motorized one also. Fisherman can easily control the fishing effort in terms of size or number of gears, fishing time etc in passive gears than in active gears. Moreover, most passive gears can selectively catch specific size and/ species as they have species, size and/ sex selectivity.

Disadvantages:

On a commercial point of view, passive gears are less economical as they are not bulk

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catching gears and are not as productive as active gears. Catch efficiency also is substantially lower than active gears as fish capture depends on movements of fish which itself is influenced by environmental factors. The fluctuation of environmental parameters and their influence on fish behaviour and/ movement are not well addressed by the scientific community till now and are less predictable. How fishes respond to various stimuli, is an area not well understood.

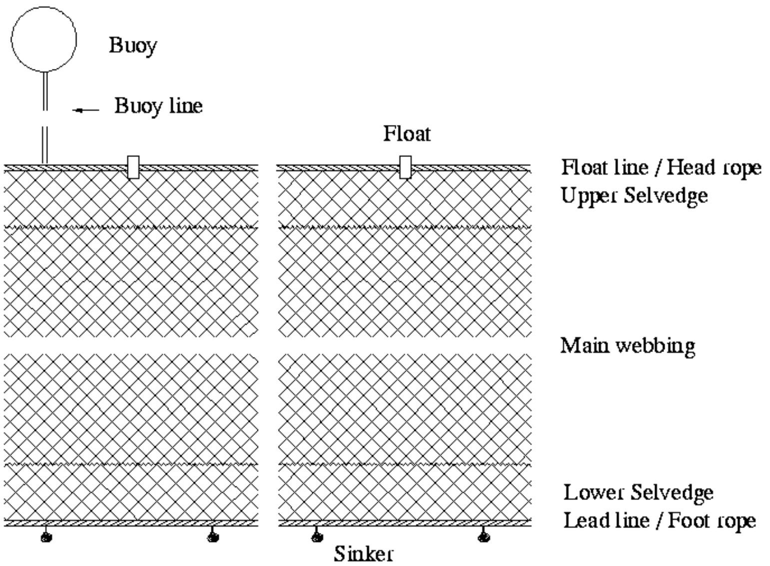
GILLNETTING

Gillnetting is an ancient fishing method and it withstood the technological and other transitional changes, the fishing sector passed through, such as introduction of bulk catching methods like purse seining and trawling. Gillnets have a number of advantages. It is a highly adaptable gear suitable for operation in the entire water column viz., in surface, column or bottom layers and can target very small fishes to large pelagics such as tuna and marlin. It can even be operated even without a vessel in small rivulets or reservoirs. But generally, a vessel is used which can be an unpowered one (non-motorized), or a motorized (small vessel powered with an outboard motor) or a mechanized one (relatively larger vessels powered with in-board engine). The gear is very simple in its design, construction and operation and requires very low energy for operation. Unlike energy intensive gears such as trawls, energy requirements are limited to commuting to the ground and back as gear setting and hauling are done manually using human power. Even in large-scale operation, when the size of the gear is very large, setting and hauling only are done using mechanical power but rest of the time the vessel is idle and simply drifts with the gear. It is a very suitable gear for catching scattered fish population. Thus, gillnetting is very popular gear across the world among all fishers particularly the traditional fishers.

From a conservation point of view, gillnet is a highly size selective gear. If optimum mesh size is selected for the net and is rigged at optimum hanging coefficient, the desired size class of fish can be caught. Compared to trawl or purse seine catch, gillnet catch is fresh, provided the soaking time is not too long. Gillnets do very less harm to the environment and habitat as seldom the nets come into contact with the fishing ground.

However, gillnets also have certain disadvantages. Though the gear is highly size selective, species and sex selectivity are relatively poor. So, in multispecies fishery of tropical area, selective operation is at a limited scale. Loosely hung nets entangle and catch non-target species including endangered animals. Chances of accidental loss of net are very high which add to ALDFG (Abandoned, lost or otherwise discarded fishing gear) contributing to marine plastic debris and ghost fishing. Mostly set gillnets are soaked for long hours resulting in poor quality catch, catch depredation by predators and gear loss.

Gillnet: It is basically a long vertical wall of netting rectangular in shape, kept erect in water by means of floats at the upper end and sinkers at the lower end. Each unit of net consists of a main netting panel (of specific yarn thickness and mesh size, made mostly of nylon/polyamide), selvedge (top and bottom), float line, lead line, gavel line/ side ropes, floats, sinkers, buoys and buoy lines depending on the target fishery. Selvedge, generally of thicker material than the main netting is provided along the edges to give protection to the main webbing during handling and operation. Floats are attached either directly to the head rope or to a separate float line, which runs along with the head rope; and likewise sinkers are attached, either to the footrope or to a separate sinker line. Floatation of the net is adjusted by the required number of floats and sinkers. Rigged net is kept at the chosen position in the water column by adjusting the floatation using buoys attached to the head rope through buoy lines. According to the type and size of the fishery, required numbers of units are tied end to end to form a fleet of gillnet. Size of the fleet varies from 30 m x 0.5 m (length x height) to more than 100 km x 50 m



Structure of a typical simple gill net

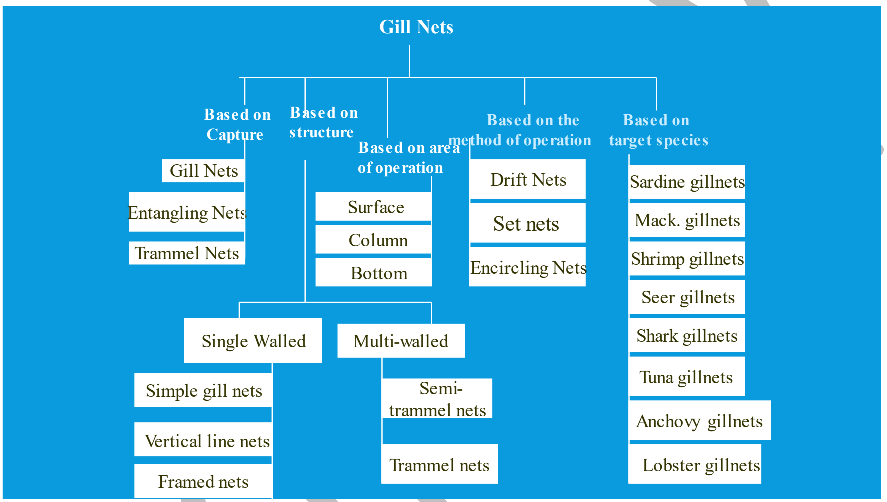
Gillnet is set across the current and in the path of fish migration. The nets shot either from the side or sometimes from the stern of the vessel are held in water for a certain period of time known as soaking time. The soaking time of the net varies from 0.5 to 1.5 h for coastal driftnets, 5-8 h for large drift nets and 12 to 24 h for set gillnets. Depending on the target fish and depth of operation, nets are held at the bottom, mid water or surface layer of the water column. In set gillnet, both ends of the gear are secured to the bottom by means of sinkers, anchors or stakes. In driftnets, one end of the net is secured to the vessel and the other end is free and the net drifts freely with the current and wind. Gillnets are deployed either during early morning or by late evening/ night. Nets operated during night have lamps attached to a flagpole at the extreme end of the fleet and in between to keep track of the net. In small-scale fisheries, nets deployed at shallow or at moderate depth are hauled by hand while for hauling large nets operated in deep waters, net hauler, power block or net drum are used.

Classification

The gillnet sector is classified into non-motorized, motorized and mechanized sub-sectors based on the vessel category and mode of propulsion. Gillnets are generally classified based on type of capture, structure, mesh size, area of operation, method of operation and targeted species. Simple gillnets, vertical line gillnets and frame nets are single walled gillnets while trammel (triple walled) and semi trammel (double walled) nets come under multi walled nets. The vertical line nets - are simple gillnets, which are divided into different sections by passing vertical lines from the head rope to the footrope through the meshes of the webbing. Frame nets are single walled nets whose slackness is increased by attaching vertical and horizontal lines between the main lines dividing the main webbing to compartments of 1 to 1.5

sq. m. Trammel nets are triple walled nets having a loosely hung centre wall of small mesh netting which is bordered on each side by tightly hung walls of large open meshes.

Depending on the mode of operation, there are drift nets (which drift freely with both ends free or with one end attached to the vessel), set nets (anchored or stalked to the sea bed) and encircling nets (the fishes are surrounded and driven from the centre by noise or other means). Classification into surface, column and bottom gillnets is dependent on the depth of water column at which they are operated which itself is dependent on the target species. Based on target species also nets are classified.



Gillnet classification

Types of gillnets

Drift gill net: Drift gill net is used to catch fishes swimming in mid-water or near surface layer. In this type, the net is drifted according to the force of the wind or current freely. A marking buoy is tied to the net to indicate the location of the net. The depth of operation of net is adjusted in relation to the swimming layer of the fish.

Set gill net: Set gill nets are usually set to the bottom by using anchors, heavy weights or are tied to poles or sticks fixed to the ground. Surface set gill nets target fishes which swim near surface water and are commonly used in shallow coastal water where the current is negligible. Bottom set gillnets are used for catching bottom dwellers and demersal fishes. In bottom set gillnet, more weight is used and only a few floats are attached to keep the net without falling to the ground.

Encircling gillnet: A long gillnet set in a circular shape around a fish shoal is termed an encircling gillnet. Fishes driven to the net by making noise, by beating on the sides of the vessel are caught by gilling or entangling. This type of gear is mostly used in shallow waters with the footrope touching the ground.

Trammel nets: Trammel nets are triple walled nets having a loosely hung center wall of small mesh netting which is bordered on each side by tightly hung walls of large open meshes. The mesh size of the outer wall of webbing is usually 4 to 5 times than that of the inner wall. All the three layers of webbing are mounted on a single head and foot rope. Fish swimming through the outer meshes encounter the center netting and push their way through the opposite outer meshes. Fish become trapped in the resulting pockets that are formed. The outer meshes on one side of the net must be a mirror image of the outer meshes on the opposite side. Semi trammel nets are of same structure as that of trammel nets except that only one layer of outer webbing is present instead of two. Trammel nets are mostly used in fresh water fishing and also for coastal shrimp fishing.

Combined gillnet-trammel nets: Simple gillnet combined with trammel net is used in certain regions. This gear is generally bottom-set and has two horizontally divided parts viz., a simple gillnet on upper part which targets pelagic and column dwelling fishes; and a trammel net at the lower part in which bottom fishes are entangled.

Capture mechanism

Mode of fish capture in gill nets is influenced by the net construction, its dimensions, and the shape of the fish body. Fish gets caught in gillnets by gilling, wedging, snagging and entangling but the main capture mechanism is gilling. When a fish approaches a gill net, it tries to pass through the mesh the size of which is selected in such a way that it is large enough to allow the fish's head but not the rest of the body to pass through. When the fish tries to push through the mesh, beyond the head region, it senses obstruction and tries to pull back. By doing so, pressure exerted by the mesh at the opercular region of the fish opens the opercula and the twine of the mesh rolls and held behind the opercula. This characteristic capture mode is designated as `gilling'.

By snagging, the fish is held tight by the twine of the mesh around its head while by wedging, the fish is held tight around its body, and by entangling the fish is held in the net by the teeth, opercular spines or other protruding appendages of the body without actually entering the mesh. Looseness of the net and the body shape of the target fish determine the capture mode. Gill net is the only gear in which `mesh' of the net serves the dual function of `selecting' the fish to be caught and catching it.

Recent trends in gillnetting

Changes in gear material and accessories, method of operation, use of resource specific gear, motorization and mechanization are the major trends observed in the gillnet sector in recent years.

Improved materials-Netting & accessories

Netting material has been changed from natural materials such as cotton/hemp/sisal etc. to synthetic fibers. By late 1950s with the commercial production of synthetic fibres, natural gillnet material has been completely replaced by nylon multifilament initially and later by nylon monofilament. In large mesh gillnets targeted for tuna and other large pelagics polyethylene (PE) material also is used for gillnets. These improved materials have higher catching efficiency than natural materials. Nylon monofilament gillnet is 7.5 times more efficient than cotton gillnet and 3 times more efficient than nylon multifilament gillnet. Besides, synthetic fibres are durable and lasts for a long period and their maintenance cost is almost nil. Likewise, rope material also has been changed from coir, manila, jute etc to PE, polypropylene (PP) etc which are strong and durable. Floats used in gillnet for buoyancy also have been changed from natural to synthetic materials. Wood/bamboo/cork /glass/aluminum etc have been replaced to plastic -styrofoam, polyvinyl chloride (PVC), thermocole etc. These synthetic floats are durable, highly buoyant, retain buoyancy, have high pressure withstanding capacity and are suitable for high sea operation. Sinkers used as weights also have been replaced from stone, clay, brick etc to lead, iron, cement, concrete etc.

Resource specific gears

With the availability of a variety of machine-made netting in a wide range of mesh sizes, gillnetting has become more resource specific.

Method of operation:

Another recent trend in gillnet sector is the switching over from encircling operation to drift gillnetting. With the introduction of smaller versions of efficient encircling nets and seine nets, encircling gillnets have become less popular.

Mechanization & motorization

Introduction of mechanized and motorized vessels was a major development in the sector. Bigger and highly powered fishing vessels led to use of bigger sized gear and helped for operation in deeper and distant waters. Vessels were altered to suit multi day operation by installing insulated/refrigerated fish holds, larger fuel tanks etc. Thus, a shift from single-day operation to multi-day operation extending to several days has taken place in mechanized sector and to a lesser extent in the motorized sector. Mechanized setting and hauling helped in handling large gear, ease of operation, reduced hauling time & trip time resulting in good quality catch.

Diversified deep sea gillnetting

To outlive the competition from large mechanized sector using active gears, traditional gillnet fishers adapted to deep sea fishing by acquiring larger vessels fitted with modern navigational, communication and gear handling equipment.

Baited gillnets

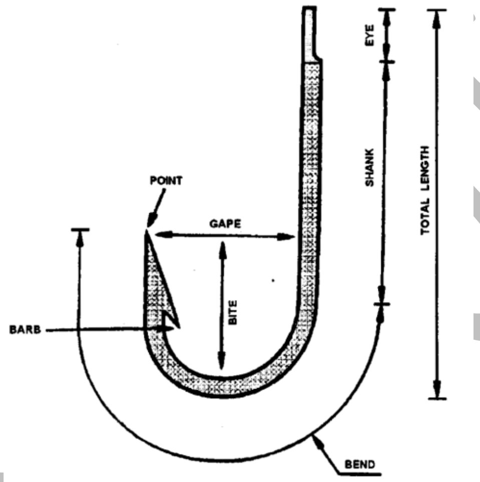
Another recent development in gillnetting is baiting the nets to increase fish density around the nets for better catch. Low value fish or damaged /discarded fish are placed in net pouches which are attached to head rope at every 10 m.

Hook and line fishing

Hook and line fishing is among the simplest of fishing gear and considered as the most ancient type of fishing. In hook and line fishing, fish are enticed by edible natural bait or artificial baits or lures and are held by the hook concealed in the bait. It is a very popular fishing method as it is eenvironment-friendly, land good quality catch, it's highly energy efficient, selective and is able to be operated in areas not accessible to trawlers viz., rocky and coral areas and in very deep grounds. It is relatively simple in design and need very low investment. The only disadvantages are that in long-line fishing, especially those operated in deeper areas, chances of incidental catch of seabirds, sea turtles and fishes other than target species are very high. Besides, bottom-set longlines snag and damage benthic epifauna causing habitat damage.

Handline, troll line, pole and line, squid jigging and long lines fall under hook and line fishing, among which handline and long line fall under passive fishing.

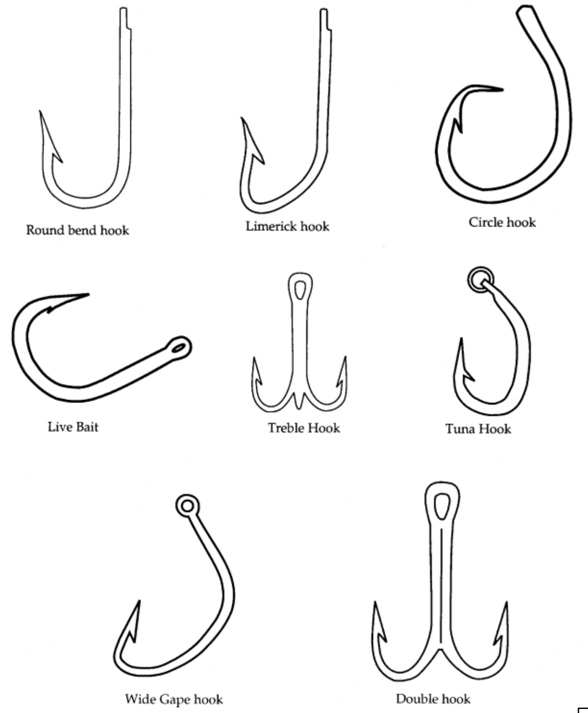
The Hook: Hook is the principal implement in line fishing. A typical hook has different parts namely eye, shank, bend, gape, bite, point and barb. The line is attached to the hook eye. The shank is the leg of a hook, which extends from the bend up to the eye, and could be short, regular or long depending upon the hook's design and usage.



Source: Thomas et al., 2007

Parts of a typical hook

Hook shanks are of different shapes such as straight, curved and barbed. Bend is the main distinguishing characteristic of a fishing hook while the gape is the
shortest distance between point and shank. The point, is the tip of the hook that penetrates the body of the fish. It occurs as straight, reversed or even curved. The barb helps in holding the bait and also prevents the escape of fish, once it is hooked. Usually, one barb is provided pointing to the inner side of the hook while hooks with one to three barbs pointing to the outside are also available. Barbless hooks also are used for fishing especially in recreational fishing.



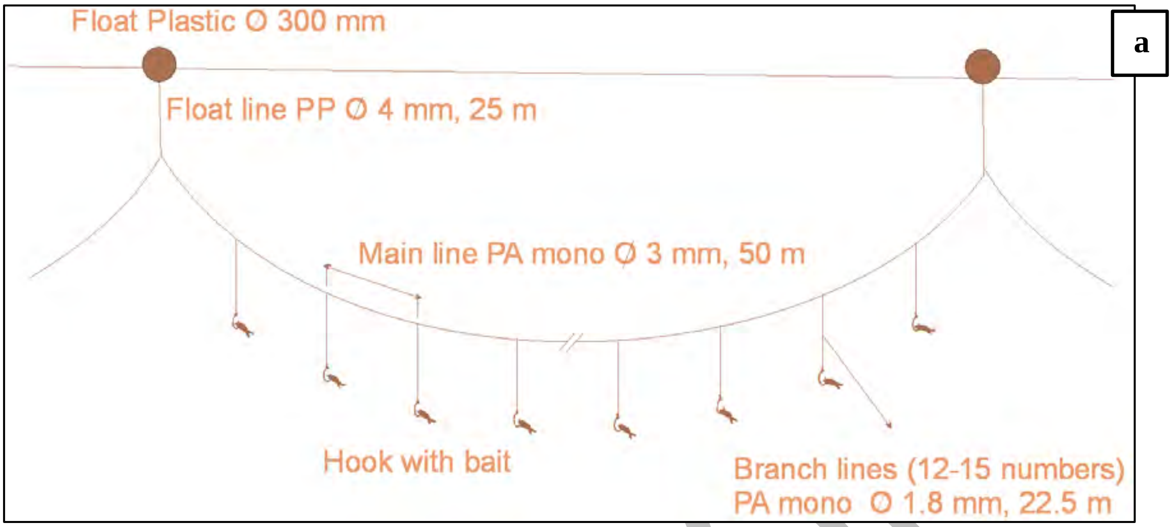
Source: Thomas et al., 2007

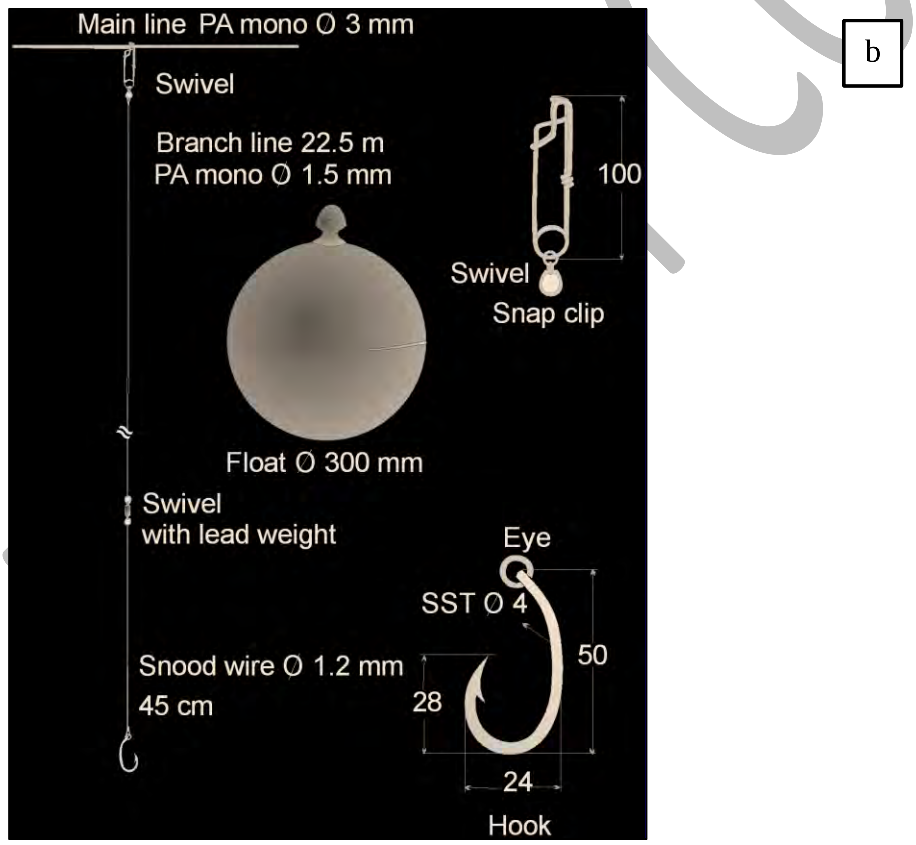
Fig. Common hook types

Handline: Handline is the simplest form of hook and line gear consisting of a hand-held single line, with rod, weight, and with one or more hooks spaced along the far end of the line. It consists of a single vertical line with single or several branched hooks. A weight is attached to the end of the line. Swivels are used to prevent excessive fouling and kinking of the line. It is operated by simply dropping the baited hook into the level of the sea. Hand liners generally use natural baits. Hand lines with or without pole are operated from boats, canoes and other small decked or undecked vessels or even from shore without even using a vessel. Lines are usually hauled manually and sometimes taken up using rollers fixed on the side of the vessel.

Long lining: Long lining is especially suited to catch scattered fish both pelagic and demersal fishes. Long line fishing is extensively used around the world on a large scale targeting mainly tuna and other large pelagics. It is one of the most effective fishing methods to harvest tunas.
A typical long line consists of a mainline, branch lines/gangion/snood, hook and the bait. Hooks and branch lines can be attached to the mainline by using knots or mechanical crimps or clamps. Buoys, buoy lines, sinkers, swivels and connectors, flag poles, light buoys, radio buoys and radar reflectors are other accessories used in largescale longlining. In small-scale operations, sections of main line with required number of branch lines are kept coiled in units known as baskets. In the monofilament long lines (monolines), the main line is continuous and stored on powered reels.
The hooks are baited and cast after clipping to a long main line to which are connected number of branch lines by knots or through clips or crimps. Swivel is attached to each branch line to avoid kinking and twisting. Depending on the size of the fishery targeted, the number of branch

lines vary. The total length of the gear especially in drift lines nowadays comes upto 80 to 100 km.





Typical structure of a long line (a) horizontal long line (b) Branch line

Depending on the mode of operation, two types of long lines are common, drift long line and set long line. Drift longlines are deployed with one end of the line attached to the vessel while to the free end, a buoy and flag pole are attached. The gear is soaked for a long period, about

5-6 hours and it drifts freely with current and wind.
In set long lines both ends of the gear are fixed to the ground using anchors or stakes or by any other means and are left unattended for hours. On either end, marker buoys are attached to trace the location. Drift longlines generally target pelagic fishes while set long lines target demersal species.

Long lines are set over stern and hauled over the bow or side forward. A baiting table and chute are generally located on the stern to facilitate shooting operation. Hauling is generally done manually if the number of hooks/lengths of the gear is small while large gear with large number of hooks is hauled by using line hauler or powered drums. The baited branch lines are attached to the main line as it is released during setting operation. On hauling, the branch lines are removed from main line and stored separately. Long lines targeting fishes that feed during daylight are set early in the morning before sunrise and hauled by afternoon. For fishes that feed during night, long lines are operated at sunset and hauled before crack of dawn.

Recent trends in line fishing

Change of material

There has been a change in the material of fishing hooks, line and poles used.

Hook material: Earlier, hooks were made of sharp objects such as shells, animal bones, stone, wood, bamboo etc. Now there has been a change in the material from natural materials to high-carbon steel, metal alloys, stainless steel etc. most of which are covered with corrosion-resistant surface coatings. Latest innovation is to use non-reflective hooks which have low-visibility under water.

Fishing line: Material change has happened in fishing line also, from natural materials such as cotton, coir, jute etc to synthetic fibers like PP, nylon monofilament, braided "super" lines, ultra-high molecular weight polyethylene etc. Fluorocarbon line is a recently introduced material which is nearly invisible to fish. These fibres are thinner, stronger, shock resistant and durable.

Fishing rod: There is a shift in the material of fishing rod also viz., from bamboo, wood etc to fibreglass or carbon fiber (graphite) which are very strong, light in weight and durable. Material changes from natural to synthetic/man-made have come in the case of floats and sinkers used for line fishing also.

Hook technology: The trends in hook technology are in terms of hook shape and hook sharpness to maximize capture rates and minimize fish loss

Shape: Circle hook is used nowadays to minimize deep hooking and injuries for hooked fish. This has more relevance in recreational fisheries where catch and release is practiced for conservation of resources. In commercial lining also circle hook can be used for easy removal of catch from the hook so that appearance will not be affected and catch would fetch good price. Hooks with multiple barbs and outside barbs are innovations which minimize escape of hooked fish but removal of catch is relatively difficult in this case. Barbless hooks used specially in tuna pole and line enable fresh catch by reducing capture stress.

Sharpness: By increasing sharpness of hook, piercing or cutting ability can be increased. Mechanical sharpening, chemical (acid) sharpening and nano sSmooth coating facilitate fast penetration.

Bait technology:
In the recent years, many developments have taken place in bait technology also. By using biodegradable material-based artificial soft baits, pollution due to the loss of plastic lures can be avoided. Another possibility to attract more fish towards the hook is by using fish attractant compounds such as `fish scents'..

Motorization & Mechanization: With the advent of mechanization and motorization, fishing effort has been increased in terms of vessel size, engine power, gear dimension and operation in distant and deeper waters targeting large pelagic species.

Automated long line system: is a new development in the sector which is widely adopted. Traditional long lining is a labour intensive and time-consuming fishing method while automated long lines using mechanical and hydraulic line haulers are now widely used in operations which have reduced the manpower requirements and enabled operation of large-scale long lines from relatively smaller vessels than before. Automated long line system consists of a line hauler with a mechanized method of hauling the hooks and untangling branch lines from the main line. In some systems, the branch lines are separated and stored on racks or magazines and the mainline is wound and stored on a drum. In other systems, main line along with branch lines are stored on drums. While setting, the hooks are baited by drawing through an automatic baiting machine.

Traps and pots

Trap fishing is an age-old fishing method extensively practiced across the world in both marine and inland waters. Trap is a traditional fishing gear made of structures with enclosures or chambers (one or more) to which the fish is lured or guided but escape is made difficult by means of labyrinths or retarding devices like funnels. As per FAO, traps are large structures fixed to the shore/ground while pots are smaller, movable traps, enclosed baskets or boxes which are deployed from a fishing vessel. Generally, both terms are used interchangeably. Traps are of different shapes, sizes and materials. Traps can be used to catch fishes, crabs, lobsters, shrimps or even molluscs. Trap fishing is advantageous as it is very easy to operate and require less attention during fishing. It is a low energy and less capital-intensive fishing method. The catch will be very fresh viz., it can be collected in live and undamaged condition. Trap fishing is economical as the capital investment is relatively low. Traps show a high degree of species and size selectivity and are suitable in areas with uneven bottom, where other gears cannot be operated. Moreover, traps cause least impact to the habitant and to the biota. Traps offer high potential for survival of discarded non-targeted species which is important from the point of resource conservation. However, traps are prone to gear loss and ghost fishing which is considered as a disadvantage.

As per FAO classification, stationary uncovered pound nets, pots, fyke nets, stow nets and barriers, fences, weirs, etc. and aerial traps come under the category of traps of which all except aerial traps are passive gears.

Stationary uncovered pound net is a type of trap which is a large net divided into one or more chambers, anchored either with a mooring system or fixed on stakes. Huge semi-permanent pound nets are built up by poles and bamboo screens. Long leaders of converging screens lead the fish and prawns to the openings in the final chamber or pound, while others within lead them towards smaller inner chambers. All except the final chamber are closed only at the bottom while left open at the surface. These traps are used in areas where considerable tidal influence is there and catch is trapped in the pound which is collected during low tide. Large-scale traps like the pontoon trap popular in Sweden are operated mechanically.

Fyke net is a fish trap which is a rectangular, cylindrical or semi-cylindrical net mounted on rings or hoops. It usually has wings or leader which guide the fish to the bag provided at the terminal end. The fish entering voluntarily finds it difficult to come out. The fyke net is fixed to the bottom with any suitable means like stakes or anchors. It is generally operated by hand and small canoes are used for operations. The fyke nets are left in the same location for several days. Compared to pound nets, fyke nets are smaller in size.

Stow net/Set bag net is a type of trap set mostly in estuaries and coastal waters near to shore where there is tidal influx. It is a stationary filtering device set in a moving water, which filters out the catch which are swept more or less passively by the current, and is retained by the force of the current. It is a conical bag net with a rectangular or square mouth followed by a body comprised of different sections and with a codend or bag at the terminal end. The net is mostly anchored to the ground using stakes fixed to the ground or by anchors or weights. A series of nets are set in a line.

Barriers, fences, and weirs: These are a group of gears operated in tidal waters. Principle of operation is almost similar to pound nets. They have a narrow leader portion ending in a broad chamber in which fish is trapped. It is made of sticks, nettings or poles. These are also operated in shallow coastal waters, estuaries etc where significant tidal action is there.

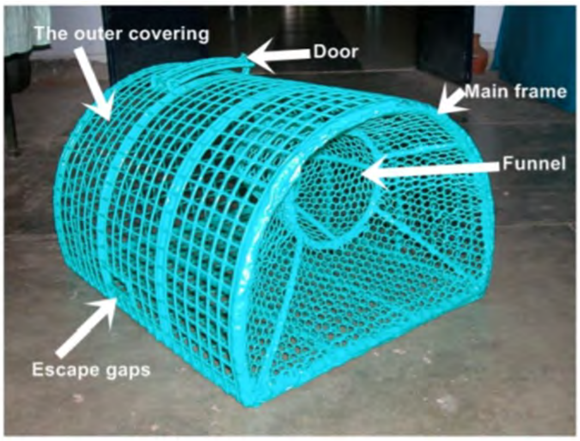
Traps/Pots: Pots and traps are rigid structures into which fish is enticed with bait or even without bait through funnels and once entered the exit of fish is made difficult. Designs of traps vary as per the target organism. A variety of traps/pots are used in inland, coastal and marine waters to catch fish and shellfishes. In most of the traps, a cone-shaped entrance tunnel is provided.

Traps targeting fish, lobster and crab are common and are respectively termed as fish trap, lobster trap and crab pot. Fish trap is comparatively bigger than shellfish trap. All types of traps consist of a frame made of iron and is covered with netting. The trap is open on one side and is provided with two consecutive funnels or valves made of netting inside the frame. At the end of the funnel, the bait bag or bait is hung to attract the fish. In fish traps, an opening is provided at the back side to collect the catch as fish trap is very large in size. Traps are set either individually or in a series. A canoe is used to carry the traps to fishing ground in coastal waters and mechanized boats are used in deeper waters. Trap is set at the desired location with a marker float attached to it, to identify the position. Nowadays, position is marked using GPS coordinates. Traps are deployed at the fishing ground either by fixing to the ground using anchors, weights etc or are placed among crevices in the rocks or corals. In some area's traps are laid and retrieved by fishermen by skin diving even in grounds as deep as 30 m which is prevalent in the south east coast of India. The trap is left at the ground for desired period and is hauled after desired soak time and the catch is retrieved.

Recent trends in trap fishery

Material change: In earlier days traps were made of natural materials such as bamboo, wood etc. Natural material has been changed to metal frame (plastic coated) covered with synthetic netting.

Traditional lobster trap



Modern lobster trap with escape gap

Collapsible trap: Conventional traps due to their huge size are difficult to handle and limited numbers only can be carried to the fishing ground at a time. Collapsible trap is a later development by which many traps s can be transported in place of traditional traps using a small canoe due to the foldability/stackability.

Provision of escape window in traps: By providing escape gaps/windows and by the use of appropriate mesh sizes for the netting used for covering the frames, juveniles can escape which makes the trap size selective which would help in resource conservation.

Timed release mechanism: Ghost fishing is a major problem with lost traps/pots which have many negative consequences on the biodiversity and fish stock. As a mitigation measure, timed release mechanism is developed in which the trap door is tied to the frame using easily corrodible metal or biodegradable natural fibre instead of the synthetic rope used at present. By this way, once lost, after a short period of time the trap door will be opened due to the breaking away of the material used for tying the trap door due to bio/degradation of the material so that the trapped organisms can escape.

Recent trends and advances in passive fishing methods have brought out positive and negative impacts on the fishery.

Positive impacts: Introduction of improved materials resulted in efficient gears, higher catch, durable gears and overall increased income to fishers. Mechanization and motorization enabled in using modern and large gears, ease of operation, reduced physical strain, access to unexplored grounds etc.

Negative impacts: Drastic increase in the number and size of vessel and gear; overexploitation of resources; threat from widespread use of nylon monofilament due to higher chances of breakage and chances of gear loss; bycatch in lines and gillnets by loosely hung drift gillnets and drift long lines; incidental catch of non-target organisms like marine mammals, sea turtles, sea birds etc including endangered species; ghost fishing by the lost gears as gillnets and traps are more prone to become ALDFG leading to ghost fishing etc. are the major negative impacts affecting the fishery.

Conclusion

Generally, passive fishing gears are Low Impact and Fuel Efficient (LIFE) fishing gears. In the context of rising fuel prices, fishing sector has to lower its fuel consumption, reduce carbon footprint and decrease ecosystem impacts. Passive fishing methods which generally are LIFE are to be encouraged to address this issue. Besides, these fishing methods are important from the livelihood point of view of the fishers especially traditional and small-scale fishers. However, the negative impacts of these gears cannot be neglected, but are to be addressed for the sustenance of the fishing sector.

6. Responsible fishing: Importance and implementation strategies

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What is Responsible Fishing?

The NOAA (National Oceanic and Atmospheric Administration) of the USA clearly defines the concept of responsible fisheries. "Responsible fisheries encompasses the sustainable utilization of fishery resources in harmony with the environment; the use of capture and aquaculture practices which are not harmful to ecosystems, resources, and their quality; the incorporation of added value to such products through transformation processes meeting the required sanitary standards; the conduct of commercial practices so as to provide consumers access to good quality products" (Blackhart et al, 2006). According to FAO, this concept encompasses the long-term sustainable utilization of fishery resources in harmony with the environment and the use of capture and aquaculture practices that are not harmful to ecosystems, resources or their quality (FAO, 1999). In seafood the term 'responsible sourcing' usually refers to responsible fishing – in other words fishing responsibly for wild-caught fish. Since there are many types of fisheries and many fish species the range of factors influencing what is 'responsible' practice can vary greatly (SEAFISH, 2015).

Code of Conduct for Responsible Fisheries

Fisheries and aquaculture are important sources of food, nutrition, income and livelihoods for hundreds of millions of people around the world and so more than 17O Members of the Food and Agriculture Organization of the United Nations (FAO) adopted the Code of Conduct for Responsible Fisheries in 1995. The purpose of the Code of Conduct for Responsible Fisheries is to facilitate structural adjustment so that fisheries and aquaculture are developed in a comprehensive and balanced manner under the concept of "responsible fisheries". The Code is voluntary rather than mandatory, and aimed at everyone working in, and involved with, fisheries and aquaculture, irrespective of whether they are located in inland areas or in the oceans. Because the Code is voluntary, it is necessary to ensure that all people working in fisheries and aquaculture commit themselves to its principles and goals and take practical measures to implement them.

The Code of Conduct, which consists of a collection of principles, goals and elements for action, took more than two years to elaborate. It is therefore a result of effort by many different groups involved in fisheries and aquaculture. In this respect the Code represents a global consensus or agreement on a wide range of fisheries and aquaculture issues (FAO, 1995).

OBJECTIVES OF THE CODE

The objectives of the Code are to:

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- establish principles, in accordance with the relevant rules of international law, for responsible fishing and fisheries activities, taking into account all their relevant biological, technological, economic, social, environmental and commercial aspects;
- establish principles and criteria for the elaboration and implementation of national policies for responsible conservation of fisheries resources and fisheries management and development;
- serve as an instrument of reference to help states to establish or to improve the legal and institutional framework required for the exercise of responsible fisheries and in the formulation and implementation of appropriate measures;
- provide guidance which may be used where appropriate in the formulation and implementation of international agreements and other legal instruments, both binding and voluntary;
- facilitate and promote technical, financial and other cooperation in conservation of fisheries resources and fisheries management and development;
- promote the contribution of fisheries to food security and food quality, giving priority to the nutritional needs of local communities;
- promote protection of living aquatic resources and their environments and coastal areas;
- promote the trade of fish and fishery products in conformity with relevant international rules and avoid the use of measures that constitute hidden barriers to such trade;
- promote research on fisheries as well as on associated ecosystems and relevant environmental factors; and
- provide standards of conduct for all persons involved in the fisheries sector.

World Fisheries

World per capita fish supply reached a new record high of 20.5 kg in 2018 (FAO, 2020). An estimated 59.51 million people were engaged (on a full-time, part-time or occasional basis) in the primary sector of capture fisheries (39.0 million people) and aquaculture (20.5 million people) in 2018, a slight increase from 2016. The total number of fishing vessels in the world in 2018 is estimated at about 4.56 million, a 2.8 % decrease from 2016.

Table 1. Marine capture fisheries of India

Particulars		Value
Length of coastline (km)	:	8,118
Continental shelf (km2)	:	5,30,000
Exclusive Economic Zone (km2)	:	20,20,000

Annual potential yield from EEZ (metric t)	:	4.41
Fishing villages (No.)	:	3,432
Fish landing centres (No.)	:	1,535
Fishermen families (No.)	:	8,74,749
Fisher population (No.)	:	40,56,213
Fish production (2020) (million metric tonnes)	:	3.72

The fleet in Asia was the largest, consisting of 3.1 million vessels and accounting for 68% of the global fleet, followed by Africa (20%), Americas (10%) Europe and Oceania, the fleet size represented over 2 % and less than 1 % of the global fleet. Global total capture fishery production in 2018 was 96.4 million tonnes, of which 84.4 million tonnes from marine waters and 12.0 million tonnes from inland waters (FAO, 2020). Marine fish production of India which was only 0.5 million t in 1950, increased to 3.72 million t in 2020 (DoF, 2020). This could be attained due to the introduction of various improved fish harvesting systems in India. The vital details on marine capture fisheries of India are given in table 1.

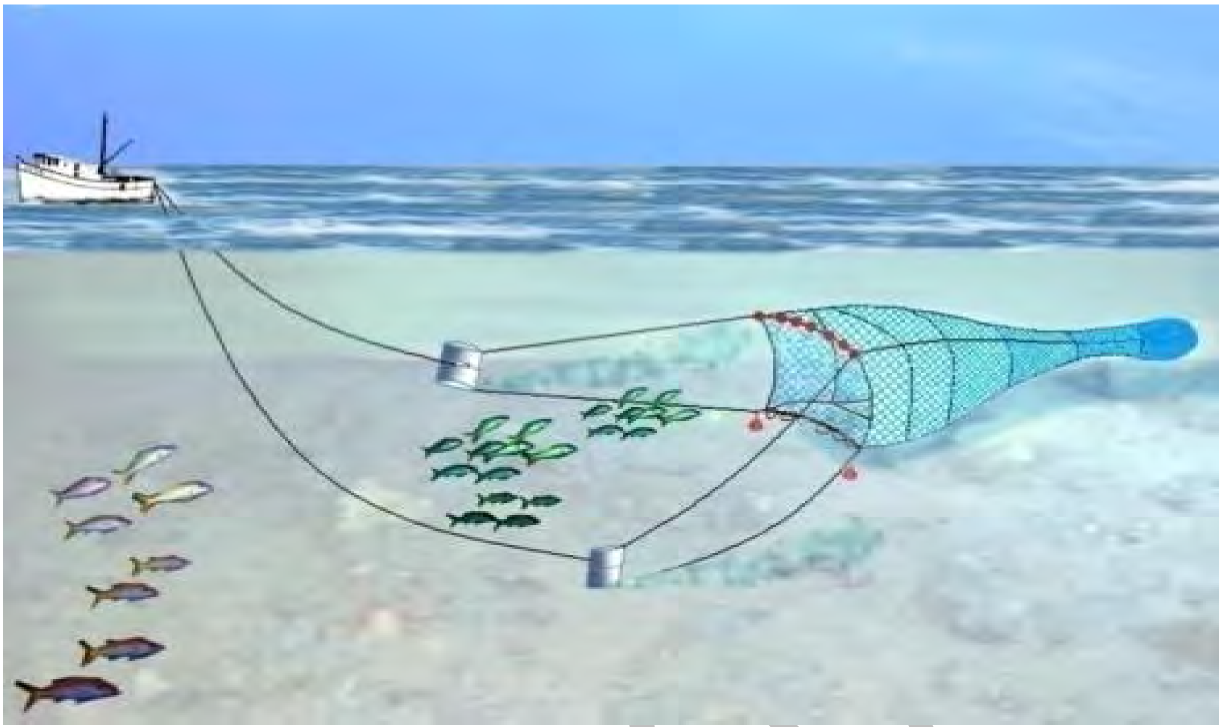
Responsible fishing for resource conservation

Responsible Fishing Gear

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

Eco-friendly trawls

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



Eco-friendly off bottom trawl system

Selectivity of fishing gears

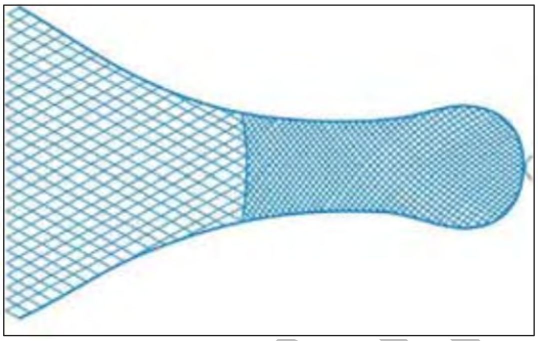
Information on fishing gear selectivity is important in biological investigations, fish stock assessment, fisheries management and for fishing gear design and development. Selectivity characteristics such as mean selection length, selection range, selection factor and selection curve of square mesh and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

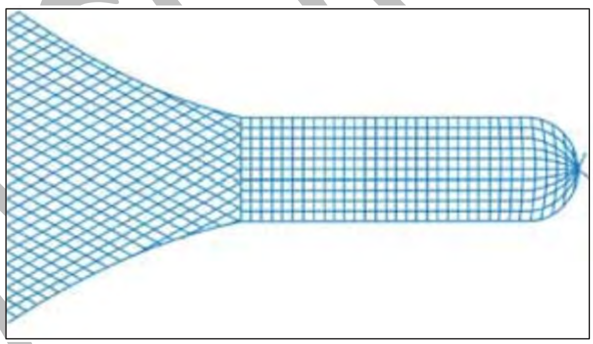
Bycatch Reduction Technologies

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

Square mesh codend

CIFT has for long been advocating the use of square meshes for trawl codend as a conservation measure. As the meshes in the square mesh codends remain open under tension during trawling, water flow will not be restricted and filtration will be efficient and resultant drag will be comparatively less which minimizes fuel consumption. As the mesh lumen remains open, it is easy for small fishes and juveniles to escape through the meshes which reduces the quantum of bycatch enabling the conservation of aquatic resources. In addition to these benefits, the quantity of net required for fabricating square mesh codend is less than the requirement for diamond mesh codend of the same dimensions, resulting in lower fabrication costs.

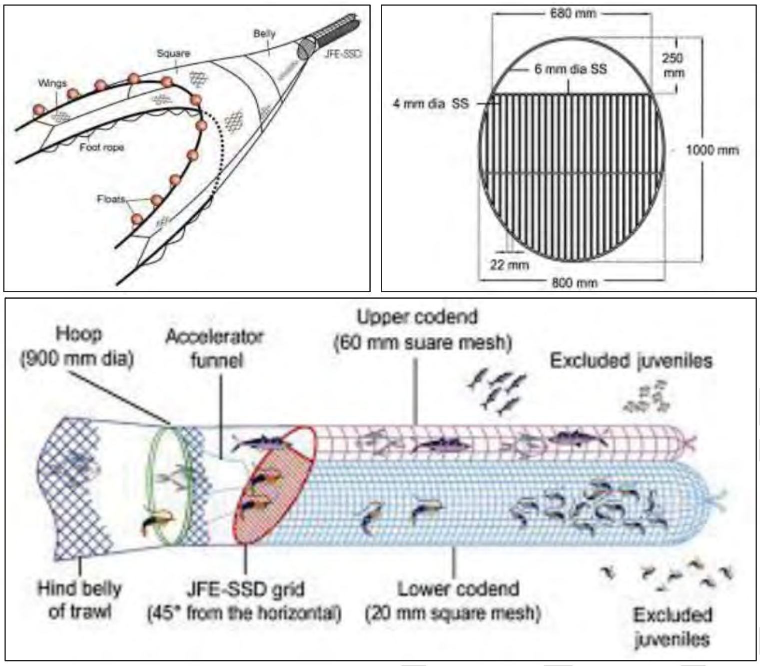




As per CIFT recommendations, Gujarat Marine Fishing Regulation Act (GMFR Act-2003) has prescribed the use of 40 mm square mesh codends in the trawl nets. The use of square meshes have been successfully demonstrated by CIFT in the Sindhudurg District of Maharashtra under a UNDP – GEF project. Most recently the Govt. of Kerala has adopted 35 mm square mesh cod end for fish trawl and 25 mm cod end for shrimp trawl through amendment of the Kerala Marine Fisheries Regulation Act.

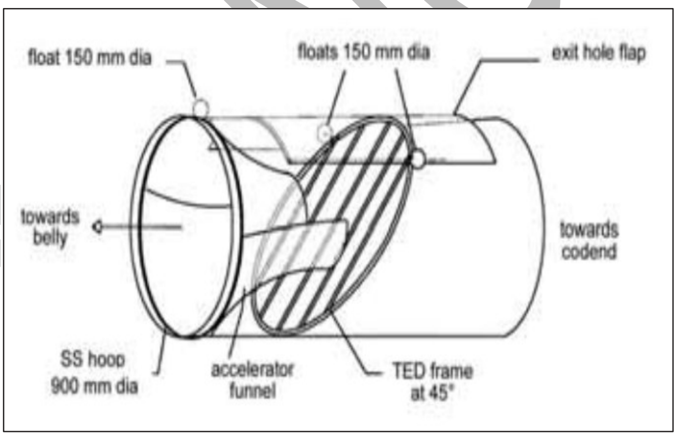
Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD)

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



Turtle Excluder Device (TED)

Sea turtles are endangered species. Incidental catches of turtles have been reported in the trawl landings of India particularly from West Bengal, Orissa, Andhra Pradesh, Tamil Nadu and southern parts of Kerala. CIFT has developed an indigenous design of the turtle excluder device which is appropriate for the Indian conditions. CIFT-TED is a single grid hard TED with top opening of 1000x800 mm grid size for use by small and medium mechanized trawlers operating in Indian waters.



Turtle Excluder Device (TED)

In the TED developed by CIFT, great care has been taken to ensure 100% escapement of the turtles while exclusion of fish and shrimp is at the minimum possible level. MPEDA, Kochi has adopted the technology and distributed about 2900 CIFT-TEDs to trawler fishermen and operators in states affected by sea turtle mortality, *viz*., West Bengal, Orissa, Andhra Pradesh, Tamil Nadu and Kerala. Demonstration cum training on Fabrication, installation, operation and maintenance of CIFT-TED were conducted at several centres in West Bengal, Orissa, Andhra

Pradesh and Kerala, in collaboration with MPEDA, Department of Fisheries, Department of Wildlife and NGOs.

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

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

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

Responsible fishing for energy conservation

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

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

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

Fishing vessel design

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

Solar powered FRP boat for inland waters

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

Fuel efficient multi-purpose fishing vessel

ICAR-CIFT has been instrumental in introducing designs of commercial, research and multipurpose vessels as per requirements of Governments and other organizations. Latest in these initiatives has been the introduction of fuel-efficient multi-purpose fishing vessel FV Sagar Harita. The vessel built under the project "Green Fishing Systems for the Tropical Seas" (GFSTS) funded by National Agricultural Science Fund (ICAR-NASF) was officially launched on 18 April, 2016. The hull of this vessel (19.75 m combination fishing vessel which can carry out trawling, gillnetting and longlining operations) is made of marine grade steel and the cabin and wheelhouse is made of FRP to reduce weight and to improve the carrying capacity and speed. The main engine power is 400 hp which is about 20% lower than vessels of comparable size. The fishing gear handling equipment such as split trawl winch, long line setter and hauler, and gillnet hauler designed at ICAR-CIFT with hydraulic power were installed onboard. RSW tanks (0 ^{0}C to -1 ^{0}C) of 2 tonne capacity have been provided for fish preservation onboard. A 600-watt solar power panel has been installed for emergency lighting and navigational aids to promote the utilization of renewable energy resource and conserve the diesel consumption. Acoustic fish detection and trawl monitoring system with underwater sensors have also been installed onboard.

FV Sagar Harita of ICAR-CIFT

Conclusion

In the context of dwindling catches from the wild the world over, there is a imminent need for all countries to implement the FAO-CCRF in totality for the sustenance of global fisheries. In

India, technology that ensure responsible fishing have already been introduced into the sector through the past few decades. The ensuring of the complaints of fisheries management regulations through vigilant monitoring, control and surveillance would bring about a responsible fisheries regime in the country.

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7. Resource and Energy Conservations Measures in Fishing Gears

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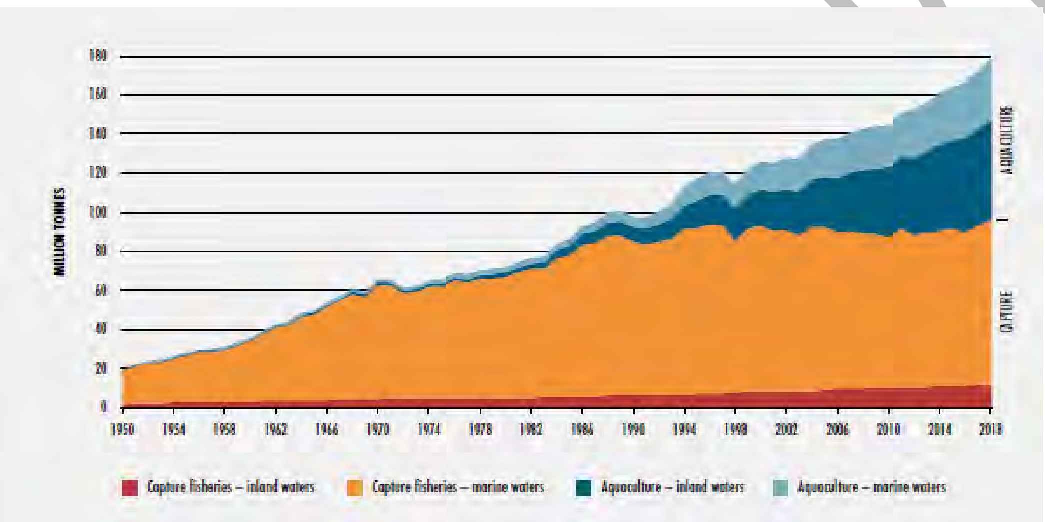
Conservation of fishery resources is the need of the hour as the demand is ever increasing, however due to various factors like IUU fishing, over exploitation and climate change fishery resources are declining. Due to the drastic declining of fish landings the entire spectrum of the fishing and fish processing industry has been affected. To sustain the fish production in the present level stringent resource conservation measures, need to be adopted urgently.

Word capture fisheries and aquaculture production (FAO, 2020)



Though the statistics is showing an increasing trend in the marine capture fish production, it may not be sustainable as IUU fishing is contributing significantly in the marine fish landings as reported by FAO and the bycatch and discards issue is continuing in the world fisheries.

Resource conservation measures

Excess fishing capacity leading to over fishing is a is a big challenge in world fisheries. Number of vessels, their size, engine power and fish hold size are much more than the actual requirement. Similarly, the dimensions of the fishing gears have been increased to several folds corresponding with the vessel size. Large sized vessel and gear and industrial fishing practices had negative impact on fishery resources, which are either touched or already crossed the maximum sustainable yield in many fisheries.

Ways to control and manage fishing capacity (FAO; 2001)

- Input control: moratorium for new vessels

Status quo should be maintained for fleet size and Government should not give permission

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for construction of new fishing vessels. License can be limited to replacement of existing vessels with only reasonable degree of escalation of the size and capacities

- Output control-catch limit

- *Fleet size regulation based on total allowable catch*

It is the total allowable catch or landings from a particular period at a particular time. This is indirect way of limiting the fishing effort. Here bycatch and discards should also be taken into consideration when quantifying the limit.

- *Regulated access based on licensing*

Fishing permit should be issued to the people who follow rules and regulations. Fishing gears can be checked periodically to implement mesh size and other regulations coming under responsible fishing practices

- *Buyback programs*

Govt. can purchase the licenses issued to the fishermen to control destructive fishing

- *Gear and vessel restrictions*
- *Area and time (fishing ban) based restrictions on fishing- MPAs/ sanctuaries*
- Followed by mesh regulation,
- minimum landing size,
- ban on destructive fishing,
- restructuring/diversification of fishing effort to under exploited areas
- Conversion of destructive fishing methods to selective fishing
- Regulation on gear dimensions
- Regulations on bycatch & discards

Mesh size regulation

Selectivity of fishing gears mostly depends on the mesh sizes and shapes. Small mesh size fishing gears usually catch variety of species including juveniles. Mesh shapes and sizes prescribed in the Fisheries Regulation Acts should be implemented properly

<u>Destructive fishing</u>:

- Non-selective fishing gears (small mesh nets)
- Bottom trawling : trawlers are considered as bulldozers of the ocean, scooping up and destroying anything in their path
- Maximum quantity of bycatch and discards is contributed by shrimp trawls
- Impact on physical, chemical & biological environment of marine ecosystem
- Pair trawling/pelagic trawling

Endangered Threatened and Protected species are landed in trawls, gillnets, lines and purse seines. Appropriate bycatch reduction devices (BRDs) need to be implemented to conserve biodiversity.

Minimum Legal Size fixed for the landings of commercially important species are another measure to control juvenile fishery.

Energy Efficiency of Trawl Systems

Trawling is the most energy intensive fishing method. Globally 50 billion litres of diesel is burnt by the fishing fleet annually. In India 1378.8 million litres of diesel was burnt in 2010 and released about 3.13 million tonnes of CO_2.

To catch 1kg of fish trawling requires 0.8kg fuel, gillnetting 0.15kg, long lining 0.25kg and purse seining 0.07kg (Gulbradson, 1986).

Drag is the most important factor responsible for fuel consumption of active gears like trawls

Factors affecting trawl drags are

Estimated drag of commercial trawls in Kerala ranges from 1.37 to 48.94 kN

design of the vessel,

- engine power
- speed of propulsion
- type and size of fishing gear and accessories
- location of the ground
- skill and knowledge of the crew
- atmospheric and sea conditions.
- design of trawl net
- rigging and operating conditions
- depth of operation, type and length of warp, etc.

Factors to reduce trawl drag	**Reduction in drag (%)**
Operate multi-rig trawls	25-30
Use thinner twine for trawls	7.0
Use large meshes in the front	7.0
Use knotless netting	7.0
Use curved otter boards (OBs)	4.0
Use optimal angle of attack for OBs	4.0
Use slotted OBs	2.0

Low drag trawls developed at CIFT

Large mesh trawl

ICAR-CIFT introduced large mesh trawls in 1970s at Veraval in Gujarat for conservation of the resources and reduce the trawl drag for energy saving. The concept was well appreciated by the trawl operators in the country and fish trawls with mesh size up to 5000mm in the wing are common at present (Edwin, et al.,2014).

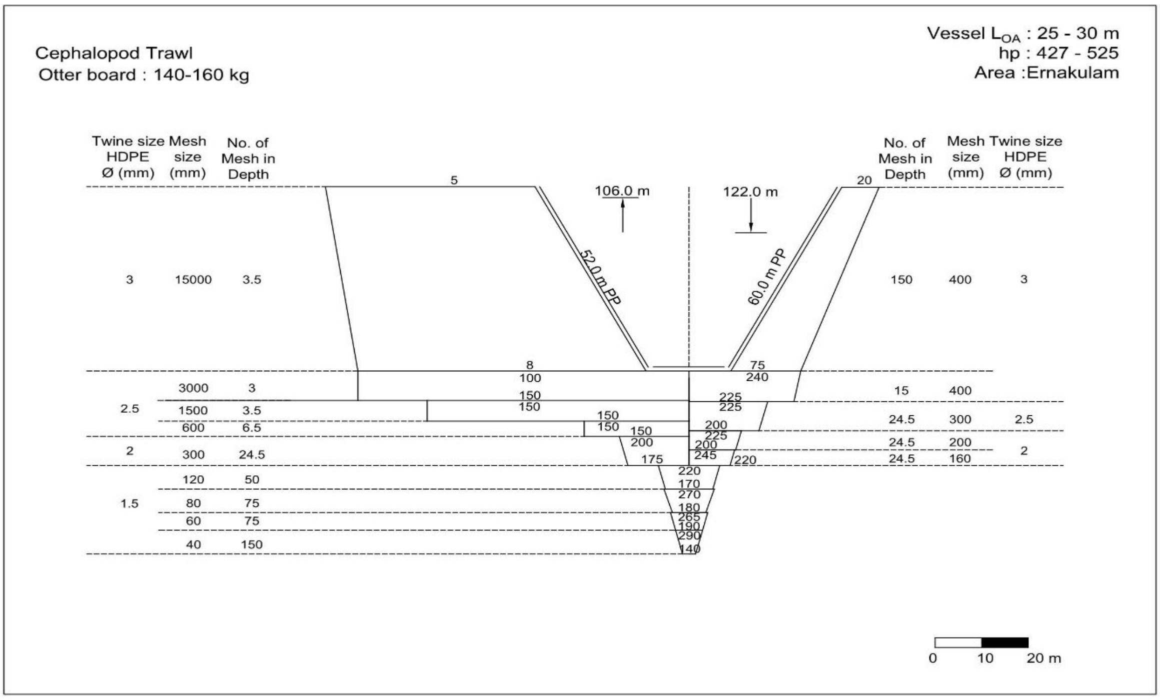


Fig 1. Design of a large mesh trawl

UHMWPE trawls

Comparative fishing trials were carried out with 24 m trawls made of HDPE twine and ultra-high molecular weight polyethylene (UHMWPE). Study revealed that average fuel consumption of HDPE trawls was 31.86±1.25 l-h whereas it was 25.31±1.38 l-h for UHMWPE trawl. CPUE were 8.1 kg h-1 and 7.9 kg h-1 for UHMWPE trawl and HDPE trawl respectively. Results shows that material substitution, coupled with improvement in trawl design, appropriate gear accessories and towing speed can help significantly in reducing the drag and concurrent reduction in fuel use.

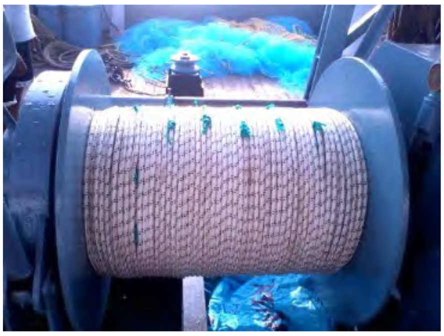
Particulars	UHMWPE trawl	HDPE trawl
Head rope length	24.0 m	24.0 m
Weight of netting	8.0 kg	14.48 kg
Twine size	1, 0.85, 0.75 mm	2, 1.5, 1.25 mm
Drag of the trawl	12.6 kN	14.83 kN

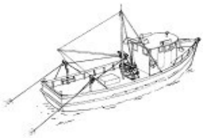
Fuel consumption	26 liter/h	30 liters/h
Cost for a net	Rs. 48,609.0	Rs.17,264.0
Expected life	2year	1year
Reduction in av. annual operational expenditure	7.5%	

Fig.2 UHMWP trawl under operation

UHMWPE Trawl warps onboard CIFT research vessel MK -II

- Steel wire rope
- Combination rope





- Low moisture absorption
- Chemical resistant
- High thermal conductivity
- Low dielectric constant
- FDA compliant
- Low coefficient of friction
- Self-lubricating
- Resistant to UV radiation

- Greasing not required/ clean deck
- Strong & durable
- wear resistance, impact resistance and low friction (wet and dry conditions)

Semi-pelagic trawl

Semi-pelagic trawl system was developed as an alternative to shrimp trawling and it reduce the trawling impact on benthic ecosystem as it is operated 1-1.5m above the sea bottom. High aspect ratio Suberkrub otter boards are used for better opening of the net. Shoes of these boards periodically only touch the bottom and front weights or depressors are used for vertical opening. The trawl system is selective, resource friendly and energy efficient

Fig.3. Suberkrub otter board

44 m Cut away top belly shrimp trawl

This trawl is without overhang and top belly is partially removed to reduce the drag without affecting the catch of shrimps. Better swimming fishes can swim up from the front of approaching trawl thereby bycatch quantity is also less. Due to less twine area energy efficiency of the trawl is improved

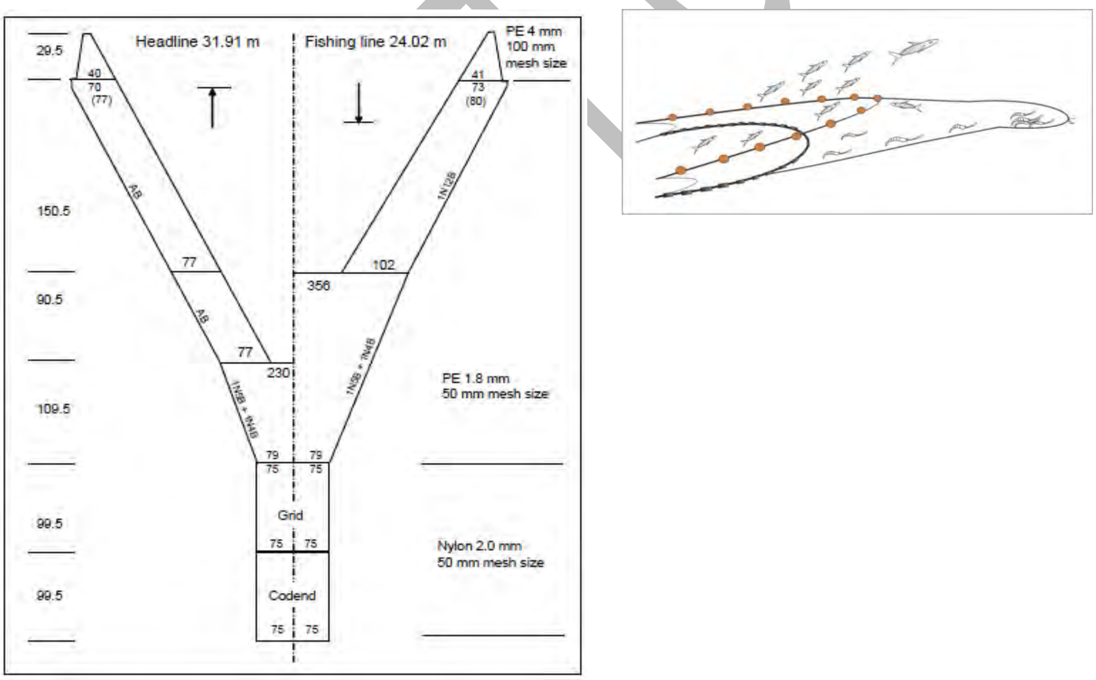


Fig.4 Cutaway top belly shrimp trawl

27m Short body shrimp trawl

The length of the trawl body has been reduced by increasing the taper ratio to reduce drag. Vertical opening of the mouth has been reduced to eliminate bycatch by reducing number of floats in the head rope. The relatively better swimming ability of finfishes compared to shrimps help them to counter the short and lower vertical height of trawl and swim out of the net. Because of the larger horizontal spread of the trawl mouth, the effective sweep area is more, which is an important requirement for an efficient shrimp trawl.

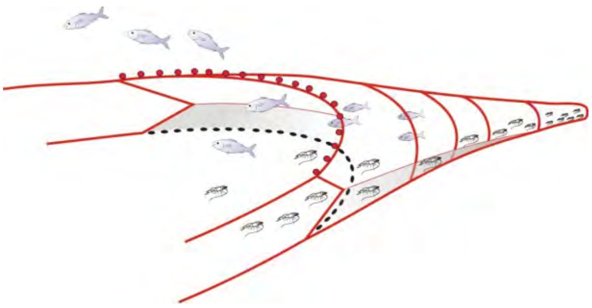


Fig.5 Short body shrimp trawl

Trawling for mesopelagics

Mesopelagic community consists of myctophids, salps, jellyfish, finfish, crustacean and cephalopods. Midwater trawl with a small mesh nylon net inner lining is required to retain the mesopelagics

Fig. 6. Mesopelagic trawl operation and the net showing inner lining and catch

Trawling for Antarctic krill

Aimed midwater trawling was conducted in fishing area 58 of Indian Ocean Sector of Southern Ocean during 1995-96 using 42m and 49m Antarctic Krill trawl with 20mm codend mesh size, after confirming the krill layer using echo sounder and positioning the net using Integrated Trawl Information system. Total catch was 1247kg of which salps contributed 53% and krill about 46%.

Fig.7 49.5m Krill trawl

Gear accessories for resource and energy conservation

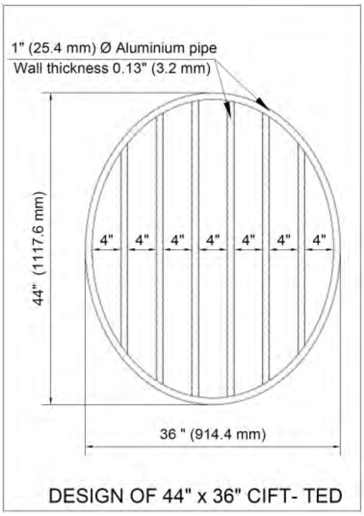
CIFT has popularised the v-form otter boards, which are stable and durable, and the performance, including trawl opening, was better. To reduce the drag of this otter board and conserve diesel CIFT has introduced the V-form double slotted bards.

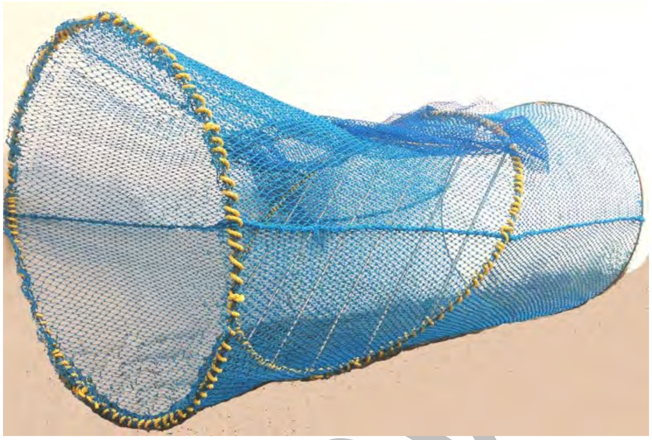
Compared to traditional v-form boards the slotted otter board showed about 2.5l reduction in diesel consumption per hour of trawling operation.

Fig.8. 1500mmx 900mm (110kg) V-form double slotted otter board

CIFT-TED

CIFT-TED was introduced to protect turtles from shrimp trawls and minimise fish catch loss. Trials revealed 100% exclusion of turtles with a catch loss of 0.19% for shrimp and 2.07% for non-shrimp.





New grid of CIFT-TED

Fig.9. 1200mmx1000mm Turtle Excluder Device

JFE-SSD

Juvenile Fish Excluder cum Shrimp Sorting Device

It is a bycatch reduction device with an in-situ sorting mechanism, which replaces the conventional codend in a trawl. The device was designed to catch shrimps and commercially important fish species using a specially designed oval sorting grid with appropriate bar spacing and dual codends. Juvenile fishes are eliminated though the 60mm upper square mesh codend

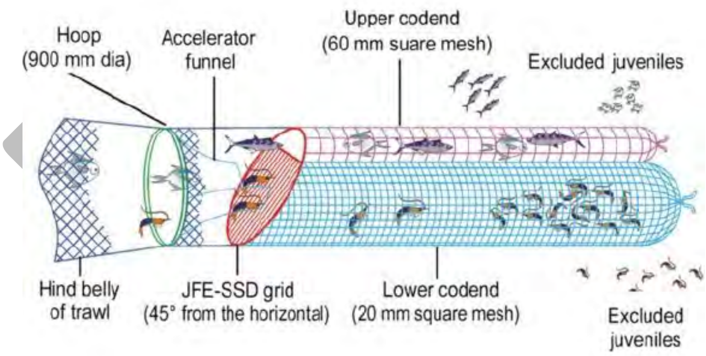


Fig.10 Juvenile Fish Excluder cum Shrimp Sorting Device

Square mesh codend with base panel

It was developed to improve the selectivity of square mesh codend by introducing a square mesh panel at the base of the codend. In the very first field trail of one hour trawling off Cochin using the new codend onboard CIFT research vessel RV. Matsyakumari-II about 150 kg juveniles of *Decapterus russelli* could be excluded through the base panel.

Fig.11 Square mesh codend with base panel

Jellyfish Excluder Device

It is a hard BRD with a metallic oval grid with vertical bars having 50mm bar spacing and an exit hole and flap cover like a TED.

Fig.12 Jellyfish Excluder Device

BRDs for bag net


Fig.13 Square mesh window fixed in stationary bag nets and bycatch from bag net

Bycatch in long line fishing

Sea birds & turtles are hooked accidentally

Area, time, and depth to be more or less selective to certain spp.

Use weights to ensure the lines sink quickly to avoid birds

Setting the lines during night reduce mortality of birds

Dying of bait,

Bird scaring line,

Underwater bait setting device are other options to reduce mortality of birds

Rescue of dolphins in purse seines

Backdown procedure

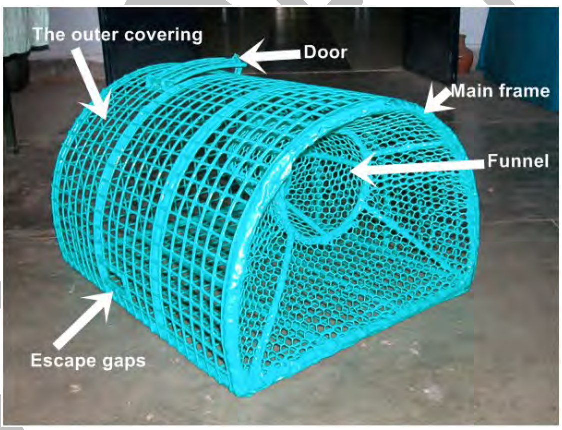
The backdown occurs after most of the net is on board. At this point net retrieval is stopped, the net is tied to the vessel and the engine is put into reverse. This creates a water current that causes the remaining net to form a long channel in the water. The water current pulls the end of the channel underwater, with the corkline sinking a few meters, thereby providing an area for dolphins to escape (dolphins remain close to the surface while the tunas are lower in the net

The **Medina Panel**, or dolphin safety panel, is a section of small-meshed webbing (net liner) at the apex of the net, which helps keep the dolphins from entanglement. It helps to increase resistance to the water flow and increase sinking of the corkline DWN is operated in Kerala, India during March to May to protect ring seines from dolphin bite. While hauling DWN encircles the original net and prevents dolphins approaching the bunt with catch

CIFT-Collapsible fish trap for estuarine fishing

Fig. 14 CIFT-Collapsible fish trap and catch

Wire trap CIFT lobster trap



Conclusion:

Responsible Fishing Gears and Practices are promoted globally for resource and energy conservation, reducing the emission of greenhouse gases, minimizing the impacts of climate change and sustainable fisheries for food, employment and income for our survival. Let us together protect the natural resources.

8. 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, 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

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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):

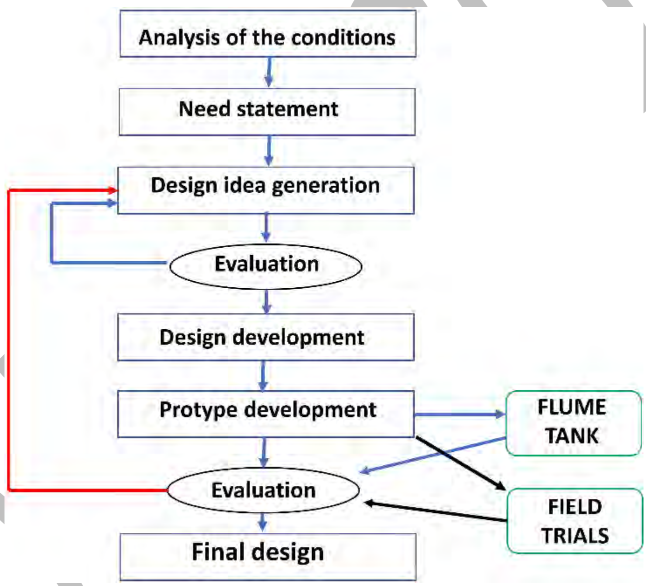

Fig. 1. Key factors involved in the designing process of a gear

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).

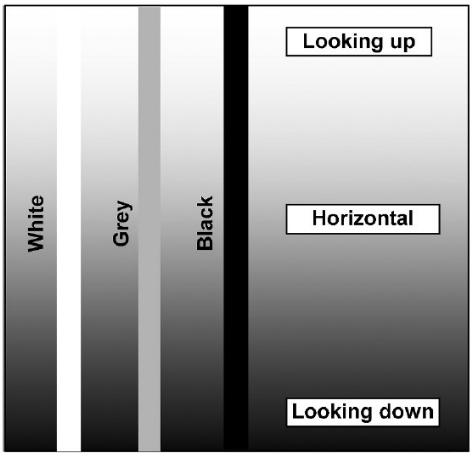

Fig 2. Contrast of white, grey and black twines hung vertically in water in relation to viewing angle (Source: He, 2010)

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.

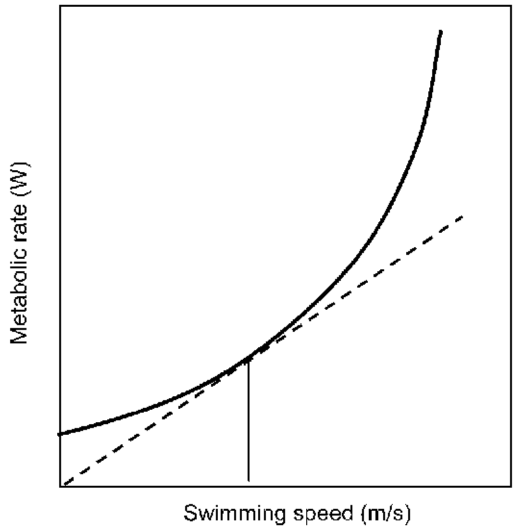

Fig. 3 Theoretical curve of the rate of work as a function of swimming speed. The amount of work per unit distance covered (J/m) is at a minimum at Uopt.

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.

9. Nano technology and its applications in fisheries

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Summary:

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

Introduction:

The term nanotechnology was coined by Prof Taniguchi, Japan in 1974 conference of the Japanese Society of Precision Engineering [1,2]. Nano technology is a domain of scientific activity oriented on synthesis, characterization, application of devices and materials and technical systems which functions at nano structures having 1 to 100 nm size [1]. Prof R. Feynman [3] American Physicist and Nobel Prize winner was the first person pointed out the importance and promising outlook for nano particles during his lecture entitled "There's Plenty of Room at the Bottom. An Invitation to Enter a New Field of Physics," delivered on December 29th 1959 at the California Institute of Technology. He pointed out that "... when we have 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

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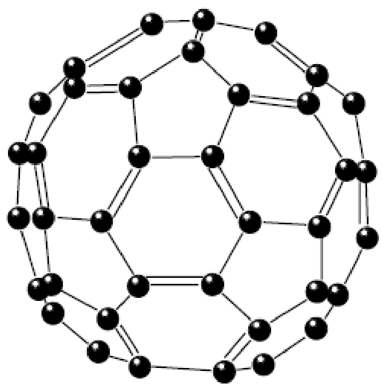
The 7th International Conference on Nanostructured materials recommended the following classification of nano materials

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

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

Carbon nano materials

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



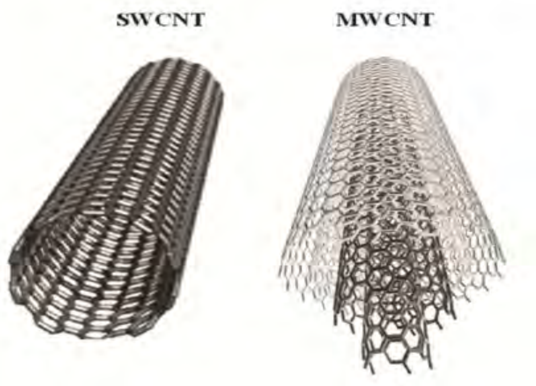


Fig 1. A) Fullerene C60 molecule B) SWCNT and C) MWCNT.

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

Synthesis of nano materials:

There are two approaches used for the synthesis of nanomaterials, viz., top-down principle and bottom-up approach [5,6]. The bottom up technology is based the development of nanomaterials of desired structure directly from "lowest level" elements (atoms, molecules, structure blocks etc). Here we have to identify the desired material in advance. The carbon nanotubes are synthesised by passing simple carbohydrates (eg acetylene) through a volume containing catalysts at a temperature of 600 – 800^{o}C. CNTs are formed on the catalysts [7]. Development of nanomaterials from larger size particles to lower sizes is termed as top-down approach. Eg. Synthesis of nano cerium oxide from cerium chloride. Dilute solutions of cerium nitrate were oxidized using ammonia under controlled environment and then calcined at 400 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 [9].

Applications of nano technology

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

Antifouling strategies:

Fig 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 [13-16]. Nano materials like gold and other organo polymeric composites were successfully employed for the development of thermochromic sensors, colourimetric sensors and electrochemical sensors for detection of contaminent in the human body or food products or adulterants. Nano engineered biodegradable material incorporated with insulin used for slow release insulin to control blood glucose concentrations [18]. Applications of nano materials in medicine are like mucosal lining treatment [19,20] and inflammatory bowel treatment using nano pharmaceuticals [21].

Food science:

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

Research in CIFT

Nano application in aquaculture cage nets

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 [24]. 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.

Different tests to verify the biofouling resistance are mentioned in detail by Ekbalad et al 2008. 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 [25, 26] described about the determination of adhesive strength using a calibrated flow channel. Diatom assays were generally carried out using Navicula perminuta [27] by suspending the treated surface in artificial seawater containing chlorophyll a 0.30 ug ml-1. After 2 h exposure the surface was 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 [28, 29]. The former bacteria are considered first settled microbes over marine exposed surfaces. The measurement was carried as per the protocols described by Akesso et al [28].

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 [22], health environment and safety issued [23]. 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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10. Energy saving fishing vessels for green fishing

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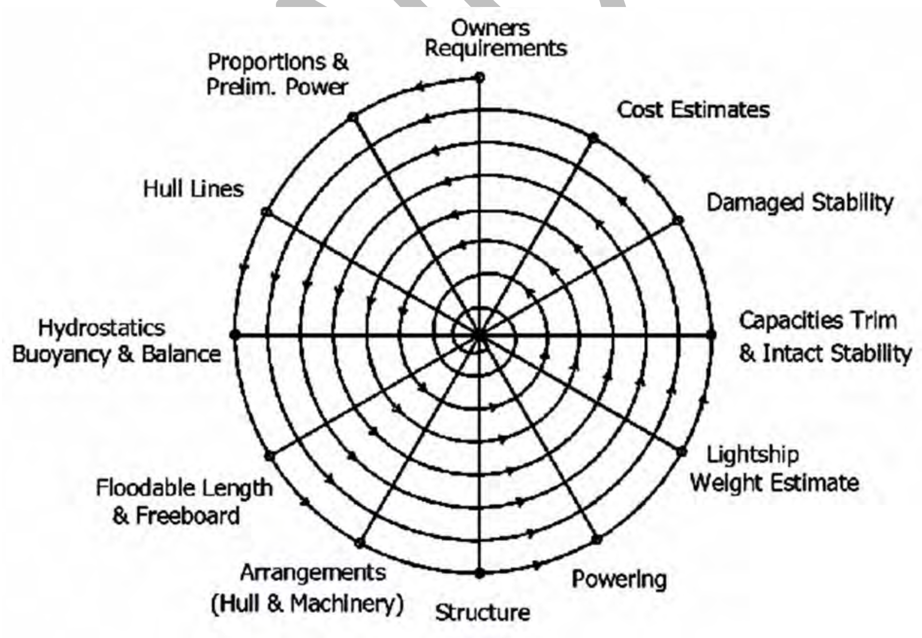
1.Census of fishing vessels

The world fishing fleet consisted of about 4.56 million (4,560,000) vessels in 2018. Globally, about 37 % of the fishing fleet is composed by non-motorized vessels. 68 % of all fishing vessels were reported to be in Asia, followed by Africa (20 %) Americas, Europe and finally Oceania (islands of Pacific). Around 40 % of the total fleet was less than 12 m in length overall (LOA). The largest vessels of 24 m LOA and above made up only about 2 % of the total fleet. (Source: FAO Fishery and Aquaculture Statistics 2018).

2.Design process

The fishing vessel design starts from the owner's requirement. The type of fishing, length, material, speed and endurance given by owner. Preliminary design is started: The main dimension & lines plan (geometry), hydrostatic particulars, machinery, structure, powering, lightship wt. are prepared.

The preliminary stability analysis to be carried out. 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.



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3.Design and construction

The fishing vessels: design and construction- rules of classification societies and the registering authorities to be followed- (standard design). This ensures the structural and operational safety of the vessel as well as the crew and all items onboard. Choose suitable material for construction-fuel consumption and maintenance aspects and operating draft are to be given importance. Optimum size, speed and volume of vessel decides the operational cost.

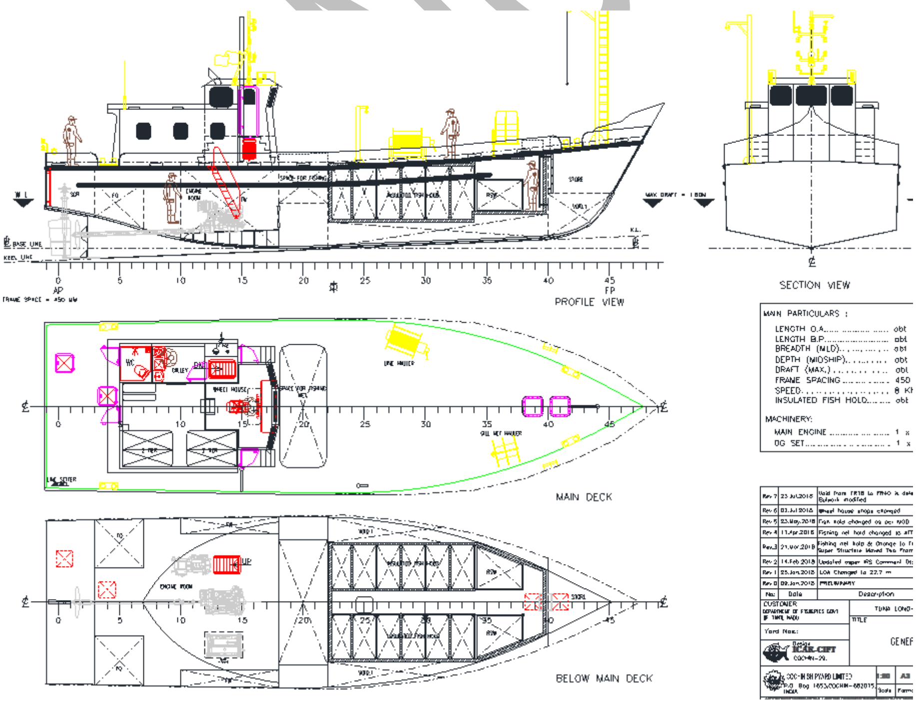
Class or National Standard organisation approved raw materials only shall be used for the construction- long life, maintenance. Main engine, valves and other machinery ate to be approved type.

Cooling/freezing, generator. To be chosen for economic operation. Efficient lay out of deck-fishing comfort, maintenance, fuel saving. Other important aspects are:
Position of wheel house, cabin – view for navigation, safety.
Selection of propulsion & deck machinery- fuel efficiency.
Suitable & Hygienic fish storage.
Safe and comfortable berth, galley, mess, toilet.
LSA, FC, LS&S.
Communication facilities.

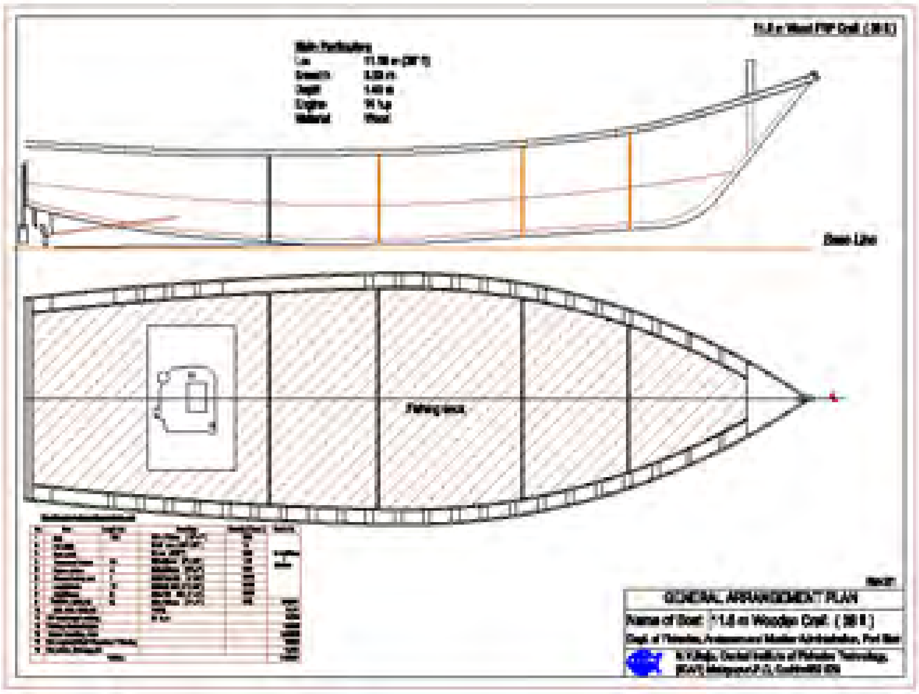
Pollution norms to be met- Global warming, cost of operation.

4. Comparison of approved and non-approved designs

4.1. Class approved designs



4.2 Non approved designs



The above design is not approved and dos not have toilet, galley and berth for multi day fishing.

5. Types of fishing vessels

1. Trawlers
2. Gill Netters
3. Purse/ring Seiners
4. Liners
5. Combination vessels, jiggers, trap,.

Trawler

Gillnetter

Ring seiner

Squid jigger

6. Energy efficiency:

This can be achieved by the following:

1. Designing fuel efficient hull form: CFD, model testing, tools
2. Making efficient propulsion system
3. Optimum size of vessel, volume (FH, Tanks)
4. Setting optimum speed of operation
5. Following operational control for fuel efficiency
6. Combination fishing in one vessel
7. Energy efficient fuel
8. Bulbous bow for fuel economy
9. Minimise the energy loss from the propulsion: engine, reduction gear shaft, propeller and appendages
10. Using ecofriendly materials for construction
11. Proper maintenance.

7. Materials of construction - fishing vessels

1.Wood: Vessel structure occupies more volume- more engine power
Eco-friendly, very low environmental impact
2.Steel: Denser than wood but thinner- engine power close to wooden
Eco friendly higher environmental impact
3.FRP: Light material, suitable for beach landing/small boats
Lower engine power, Damages environment.
4.Aluminium: Light material- lower engine power- small & medium vessels - Damages environment.

5.Ferro cement: Heavy- more engine power- Medium impact on environment. Not popular.

8. Propulsion system

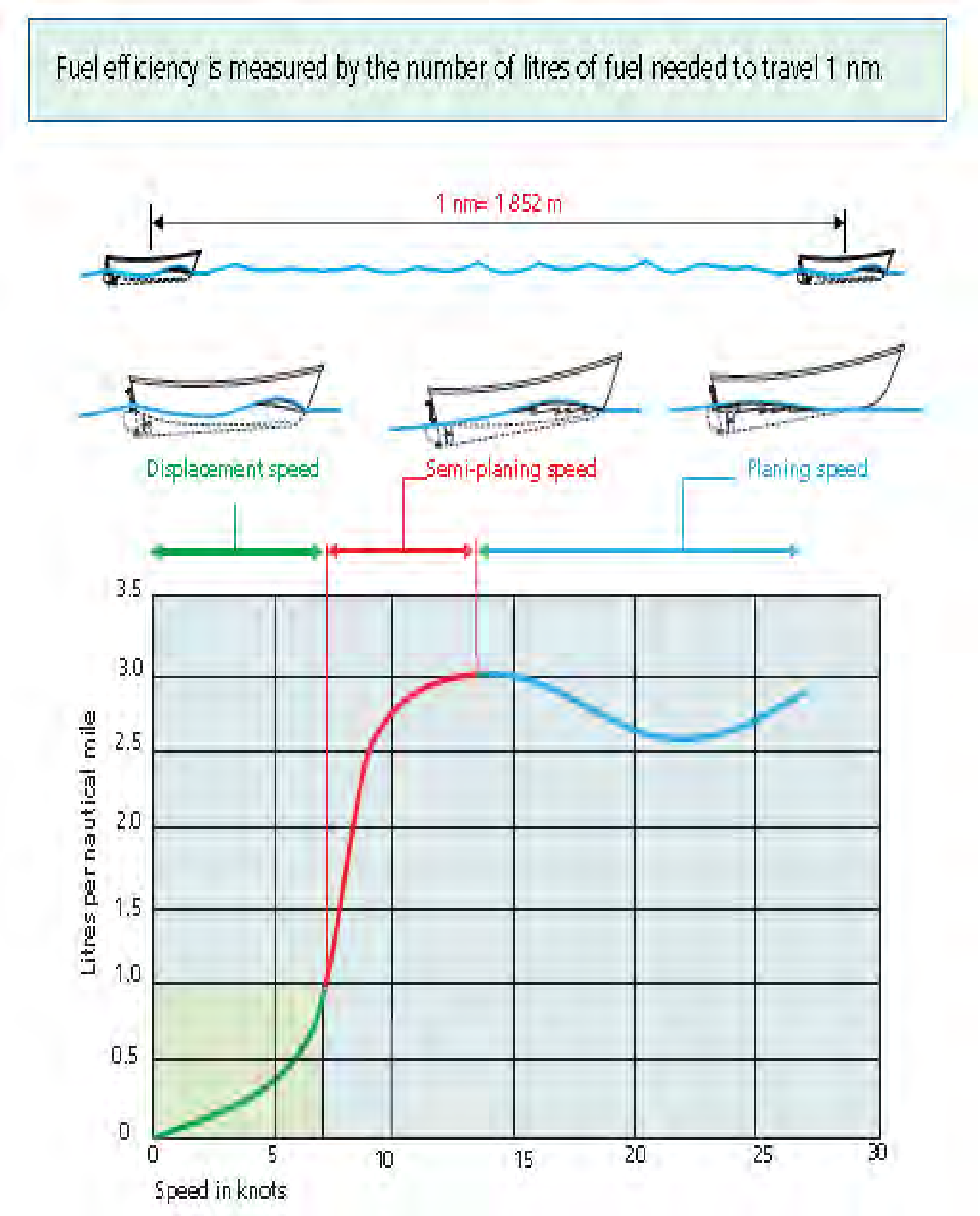
Right selection of propulsion depends on:
Main engine (power and rpm)
Reduction gear ratio
Shaft diameter-optimum
Length of shaft-minimum
Kort nozzle for trawling

9. Operational control for fuel efficiency

Depends on:
Control the following to save fuel:
Speed of: reaching fishing ground and return
Minimising unnecessary idling at harbour and sea
Cut unnecessary use of generator, fans, lights, etc
Keeping log book and making entry to know the daily fuel consumption; feeling of responsibility.

10. Speed and fuel consumption

This is explained below.



11. Fuel efficient hull form

A fuel efficient hull minimises the resistance and also the operational cost. Below gives the picture of a fuel efficient hull developed using Computational Fluid dynamics software to minimise the resistance in water. A bulbous bow can be sen attached in the forward below water which reduces wave effect during cruising.

12. Combination fishing for fuel efficiency

Making a combination vessel with two or three types of fishing will Replace 2/3 vessel with one. For example, Trawling, long lining and gill netting in one vessel replaces three vessels.

13. Alternate energy for propulsion

The following methods of propulsion are available, but only some very efficient and proven.

Petrol (Gasoline) Engines
Diesel engines
Kerosene+ Petrol
Nuclear
Solar
Hybrid, Diesel electric
LNG/LPG
Pertol+LPG
Fuel cell
Ammonia
Nuclear and ammonia are not popular due to the risks as well as the high cost. But Solar boats very good and one such inland solar fishing boat can be seen below.


SOLAR POWER BOAT

11. Fishing Technology interventions for reducing sea Turtle interactions in Fishing systems

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Sea turtles are endangered species which are protected under schedule I of the Indian wildlife protection act 1972 and its amendment in 1991. Sea Turtles are listed as critically endangered or threatened on world conservation Union Red list. Sea turtles interact with trawl gears, pelagic long line gear on the high seas, and beach seine, gillnet and shrimp trawl gears in coastal waters. These interactions can lead to death, most frequently through drowning, when the turtles cannot climb to the surface of the ocean to breathe after becoming hooked or entangled in the fishing gear. New types of gear or ways of fishing can significantly reduce the rate of interactions between turtles and gear or the mortality rate after an interaction has already occurred.

The code of conduct of responsible fisheries (FAO 1995) gives guidelines for sustainable development of fisheries, prescribes the need for protecting endangered species like sea turtles. As a signatory to the code, India is bound to conduct research, develop appropriate devices and practices and implement regulatory measures for protection of endangered turtles. The fundamental objective of responsible fishing is to maximise economic returns to the fishermen without affecting the long-term sustainability of fishery resources and with minimum impact of ecosystem

Trawling and sea turtle interactions

Trawling is considered to be a very effective method of fishing for demersal population in terms of investment and yield. Trawl nets are towed gears consisting of funnel shaped body of netting closed by a bag or cod end extended sideways in front to form wings. Trawling targets at mainly shrimps gained popularity over the years and led to the development of an organised fishing industry. Trawlers form nearly 80 % of the small-scale mechanised fleet in India. Even though bottom trawl is an efficient fishing method for targeting demersal resources, its is less a selective fishing technique. Along with the targeted resources a large number of non-target resources which include protected and endangered species such a s sea turtles are also caught during trawling. Rajagopalan *et al* (1996) reported that trawls accounted for 17.8% of the incidental catch along the Indian coasts. Along the east coast this problem has been aggravated due to rapid expansion of the mechanised fishing industry. Incidental mortalities of turtles is highest in Orrisa due to presence of large congregations of marine turtles.

An US law (section 609 of of public law nos 101 -162) introduced in May 1996 restricted imports of shrimp harvested with fishing equipment such as trawls nets not equipped with Turtle excluder devices (TEDs). The subsequent shrimp turtle case brought environmental

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requirements in the WTO into the mainstream, through its interpretation of relevant WTO articles. In view of these concerns, with respect to trade and the environment, the Department of Animal Husbandry and Dairying, Ministry of Agriculture, Govt of India constituted an expert panel to conduct detailed investigations on marine turtle distribution in Indian waters, their incidental mortality in fishing nets and use of TED in trawl nets.

TED For Indian Fisheries

The Turtle excluder devices consist of panels of large mesh nettings (soft TED) or a frame consisting of a grid deflector bars (hard TED), installed before the cod end of the trawl net at an angle leading upward or downward into an escape opening. Small animals such as shrimp slip through the mesh lumen of the netting panel or gap between the deflector bars and are retained in the while large fishes and elasmobranchs are stopped by the netting or the grid of the deflector bars and can escape through the opening (Fig 1). Thus air – breathing marine turtles were prevented from capture and subsequent death after prolonged entrapment in the trawl.

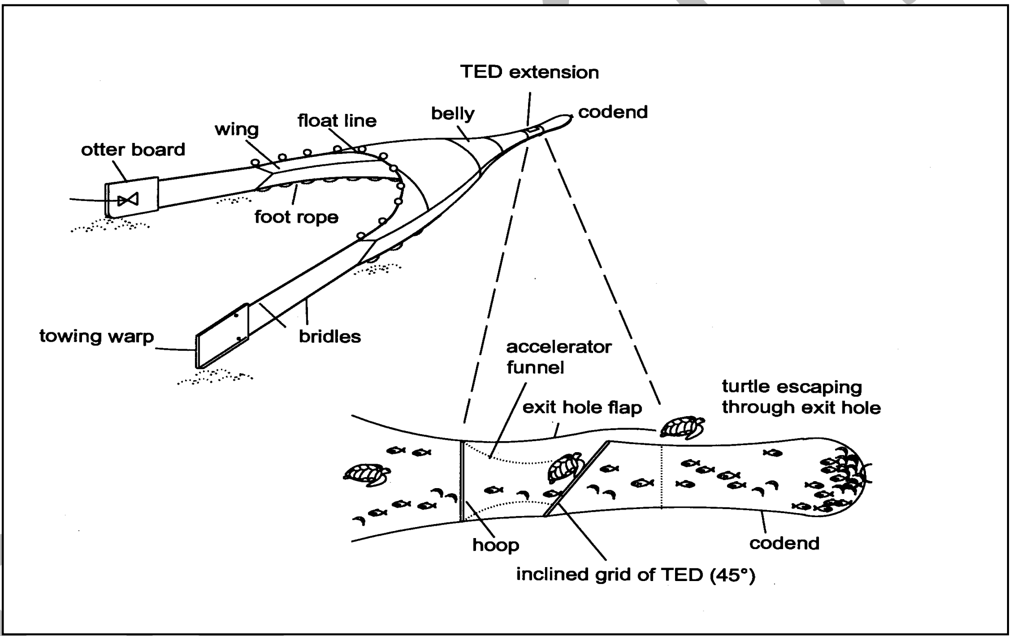


Fig1. Principle of TED operation

Different designs of TED are available today and they vary with regard to their construction, principle of operation and materials for construction depending on the target groups and fishing conditions (Fig 2). Soft TED and Hard TEDs are the two types that are used worldwide (Mitchell et al 1995, Anon 2002a) The hard TED is rigid frame device installed ahead of the cod end to separatety and exclude turtles from the trawl catch. Designs of hard Ted include Gorgia Jumper, NMFS hooped TED, Fixed angle TED, Antony Weedless, Flounder TED, Super Shooter (Watson and Taylor 1988), Cameron TED, Jones TED, Thai turtle free device.

Modifications of the basic TED design have been carried out by different nations. Thai Turtle free device was developed by Kasetsart University and SEAFDEC/TD, in Thailand (chokensanguan et al 1996, Chokesanguan 2000). The AusTED (Australlian trawling efficiency device) was developed in Australia (Mounsey et al 1995, Ribon-Troeger and Dedge 1995, Brewer et al 1998, Robins- Troeger and McGilvray 1999, McGilvray *et al* 1999) and CIFT –TED in Inda (Dawson 2001, Dawson and Boopendranath 2001, 2002a, b, 2003)

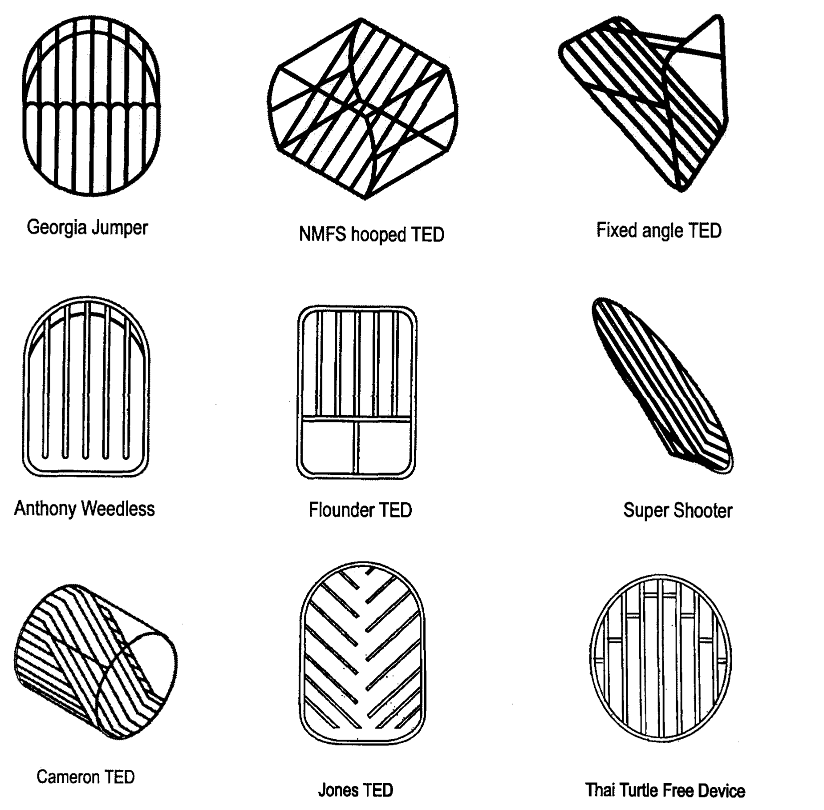


Fig. 2 Variation in single grid hard TED designs

CIFT was closely associated with evaluation of Super shooter TED designs of US origin. as envisaged under the mandate of expert scientific panel along with CIFNET with the support of MPEDA and FSI. Results of the experiments conducted by CIFT to evaluate the Super Shooter TED imported by MPEDA on *Matsya Shikari* has been detailed. (Boopendranath *et al*) The Shooter TED was of 1030 x 850 mm size with a deflector bar gap of 90 mm.

6 Fishing operations were conducted off Andhra, off Kalingapatnam at a depth of 45 – 55 m. The catch retained in the cod end comprised of catfish, perchs, pomret, seer and carangids. No turtle was retained in the experiment.

Experiments continued along the Bheemili and Chilka with a additional exit hole cod end provided at the exit hole to retain the catch excluded due to the installation of TED in the trawl net (Fig 3). During the 5 operations which was done at a depth of 45 -140 m a total of 676 kg was landed of which 469 kgs was retained in the main cod end. The results indicated an overall escapement of 30.8 % fin fish. Turtles were not retained in the main cod end or exit hole covered cod end. (Ramarao 1995 a)

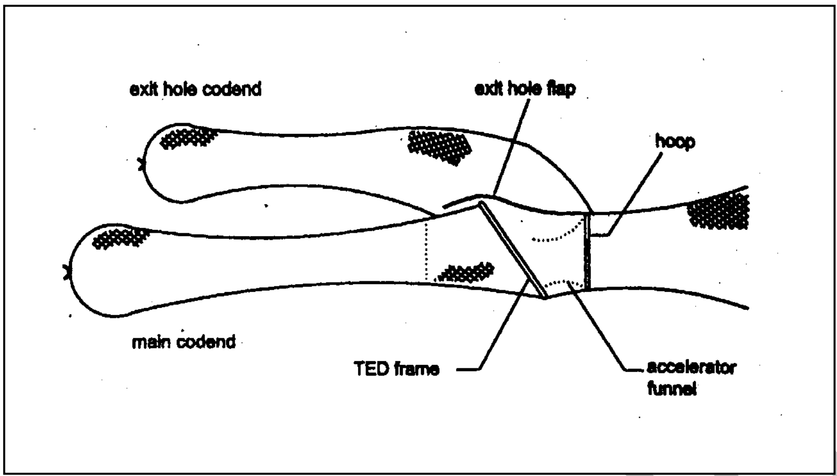


Fig. 3 – Details of rigging of exit hole cod end for experimental operations

During the operations off Andhra Pradesh using Super shooter TED on board MV Skipper in the depth range of 36 -50 m (Kirubakaran et al 2002) two turtles were excluded during the operation. The TED operations with Exit hole at the top of the net resulted in a catch loss of 13.7 %, while operations with exit hole at the bottom resulted in a catch loss of 43.3%. (Kirubakaran *et al* 2002)

Unlike fishers in USA, Australia and other advanced maritime nations, fishers on the Indian coast target both shrimp and non-shrimp resources. Experiments with TED designs which have a deflector gap of less than 90 mm in Indian waters, though successful in excluding turtles showed poor performance in retention of targeted non-shrimp catch components. Hence these TEDs are not considered suitable for Indian conditions, nor were they acceptable to Indian trawler owners and operators (Mishera and Behara 2001)

Development of CIFT-TED

An Indigenous design of TED was developed at CIFT with a focus on reducing by catch loss. THE CIFT-TED is a simple single grid hard TED with a top opening. The device can be fabricated and installed with minimum training using locally available infrastructure and net making skills at a cost of approximately Rs. 2500. The design, construction, installation and operation of CIFT-Ted have been elaborated by Dawson & Boopendranath (2002) (fig 4 -8).

Field trials and demonstration with CIFT-TED along the east coast of India

A Total of 25 field trials were conducted with CIFT TED yielding a Total catch of 889.8 kg. (Table 1) The mean catch rate in operations with a CIFT-TED installed in trawl was determined

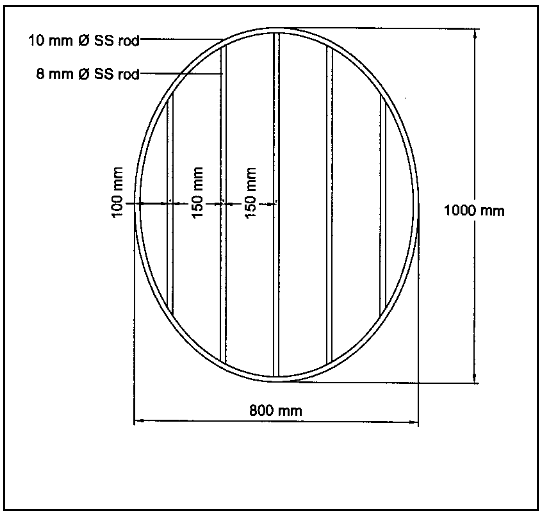


Fig 4. 1000 x 800 mm CIFT-

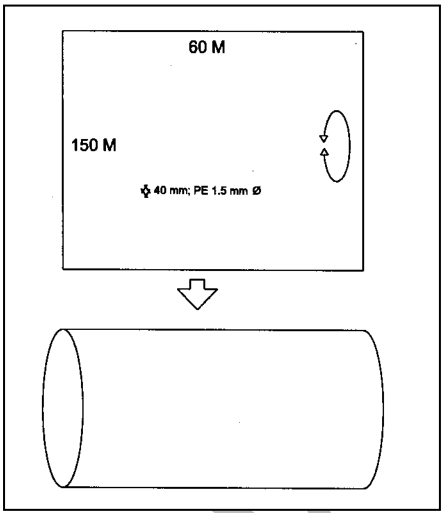


Fig 5. Construction of CIFT TED Extension

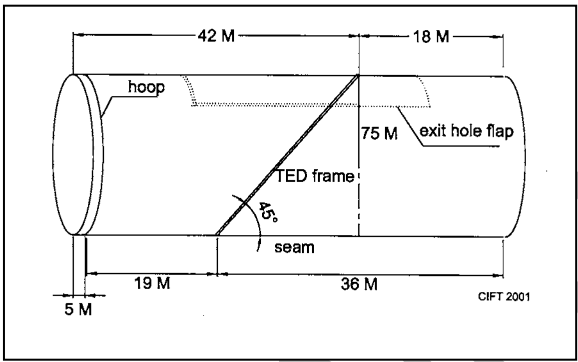


Fig 6. Fixing the grid at the correct angle

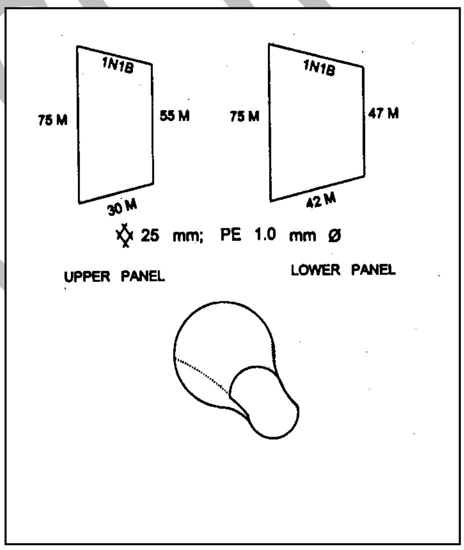
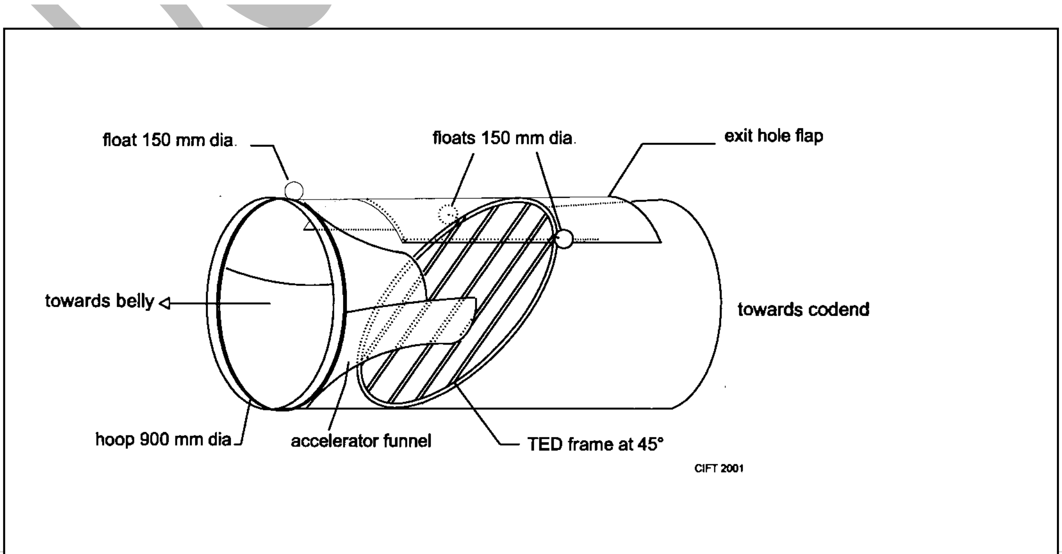


Fig 7. Construction of accelerator funnel

Fig 8. Perspective view of TED Extension



to be 35.5 kg. haul $^{-1}$. The catch composed of fin fishes Prawns, Cephalopods, Crabs, Sharks, Jellyfish. The predominant fin fishes included Pomfrets, Mackeral, Upenoids, Perches, Ribbon fish, Catfish, Bombay duck, Squilla, Silver bellies Soles, Puffer fish, Sciaenids, clupeids. Relative exclusion and retention rates during CIFT-TED installed operations along the east coast of India is given in Fig. 9. The catch loss due to CIFT TED installation was estimated to be 3.3 % for non-shrimp resources. Out of a total of 26.8 kgs of shrimp landed only 0.5 % was observed to have been excluded after the installation of CIFT TED.

Table 1. Details of TED installed trawl operations along east coast coast

Area	No of hauls	No of hours	Catch retained(kg)	Catch loss(kg)	Catch loss (%)
Paradeep (Orissa)	7	7	422.6	14.3	3.3
Dhamara (Orissa)	1	1	79.23	0.07	0.08
Astrang (Orissa)	1	1	50	0.05	0.1
Bahabalpur (Orissa)	1	1	22	0.3	1.36
Balaramagad (Orissa)	1	1	44	0.8	1.81
Visakhapatnam (A.P)	5	5	69	0.13	0.18
Kakinada (A.P)	6	6	133	1.8	1.35
Nizampatnam (A.P)	2	2	35	0.25	0.71
Krishnapatnam (A.P)	1	1	25	0.7	2.8
Vadarevu (A.P)			10	0.2	2
Total	25	25	889.83	18.6	2.09

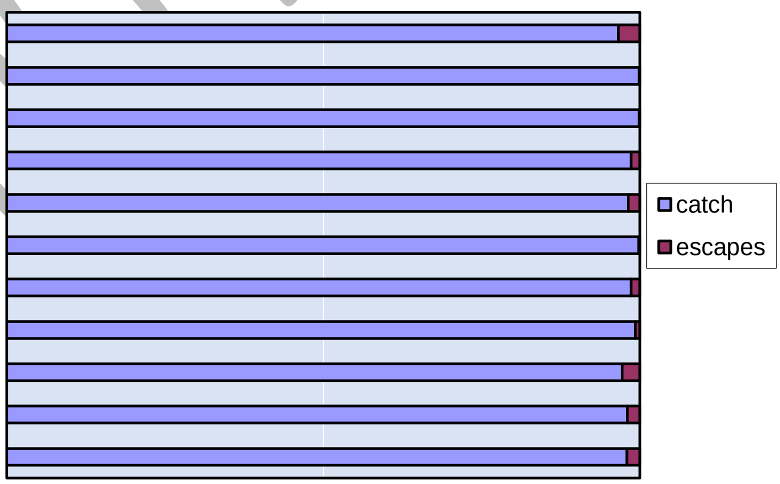


Fig 9. Relative exclusion and retention rates during CIFT-TED installed operations along the east coast of India

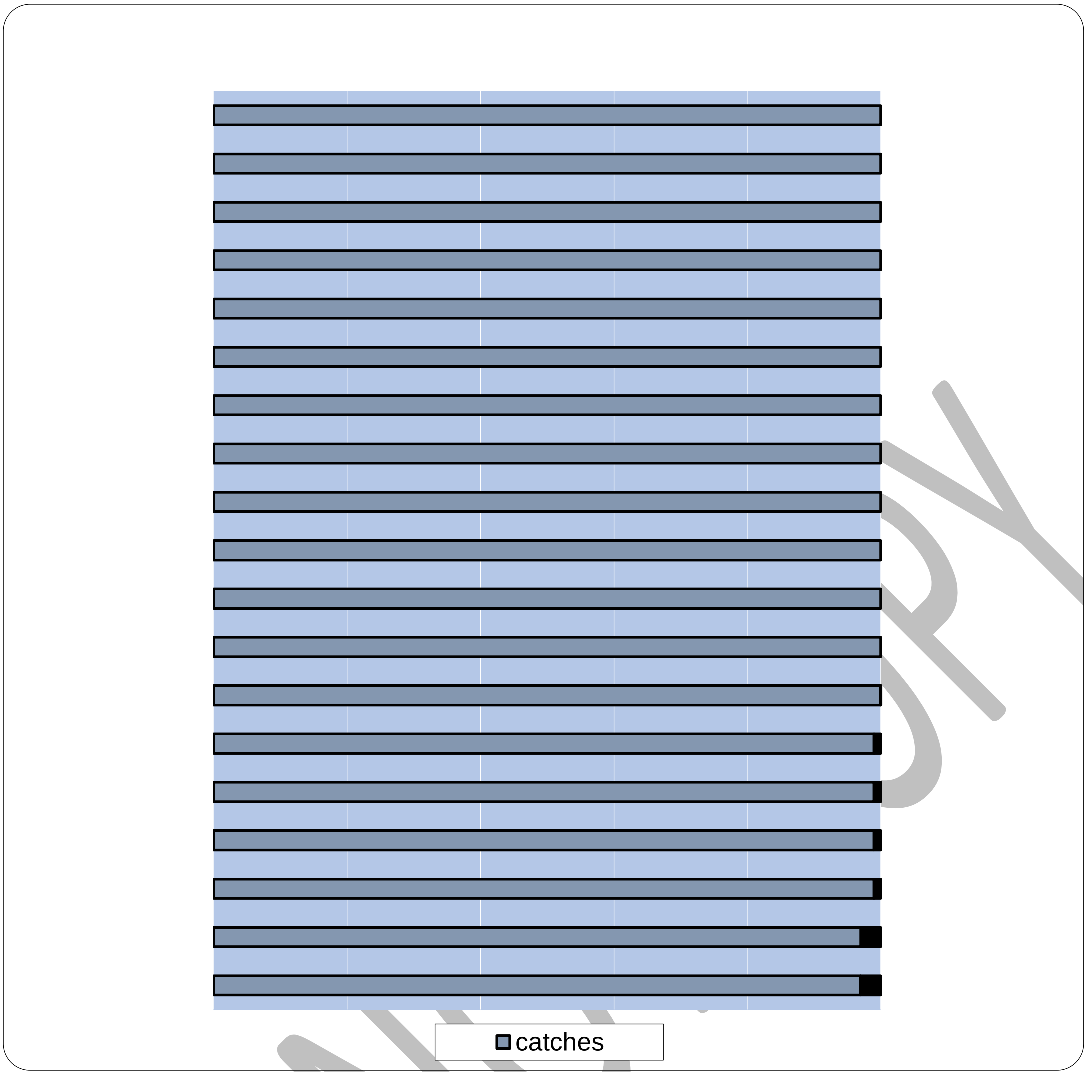
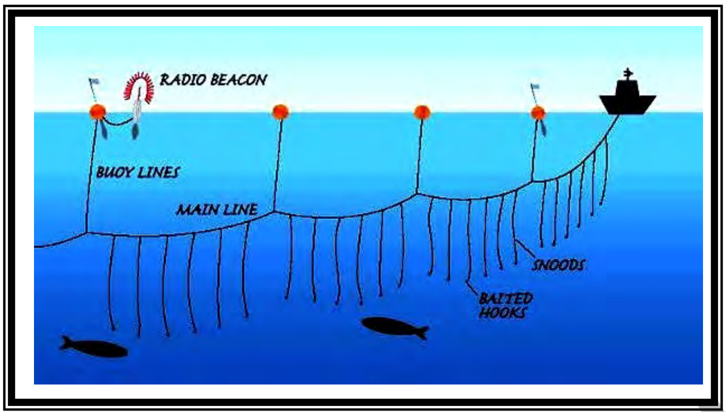


Fig 10. Relative exclusion rates of different species groups after installation of CIFT-TED durng experimental trawling along east coast of India

Longlining and sea turtle interactions

Incidental mortalities of sea turtles in pelagic long lining, a fishing method intended to catch migratory top predator fish, primarily tuna and swordfish is a global conservation concern. Scientists, managers and fishermen are working co-operatively to develop mitigation measures to reduce this mortality. Assessment of turtle avoidance measures in longline fishery contributes to a small but growing body of research. Research on methods to avoid sea turtles in pelagic long line fisheries has been initiated only recently. Most experiments had small sample sizes and had been conducted over only a few seasons in a small number of fisheries (Gilman *et a*l., 2006a). Further-more, few studies considered effects of turtle avoidance methods on other bycatch species, including seabirds (Gilman *et al*., 2005), sharks (Gilman *et al*., 2007) and cetaceans (Gilman *et al*., 2006c).



Hook Design

Most turtles are either hooked as they attempt to eat the bait or are entangled in the line. Changes in hook design and bait type were a few as measures to reduce the bycatch of sea turtles on pelagic longlines. Studies have showed that Use of large circle hooks with no greater than a 10-degree offset, combined with whole fish bait have been effective in reducing sea turtle mortality in longline fishing. Circle hooks reduce turtle mortality because the size and shape of the hooks makes it more difficult for the turtles to swallow, avoiding damage to internal organs.

These hooks are typically wider than the traditional hooks J hooks and have barbs pointed back towards the shaft of the hook, making ingestion more difficult. Therefore, even the sea turtle being caught by the circle hook, hooking position will be around its jaw and the hook can be easily removed. Circle hooks are currently being tested in many fisheries and have been proposed by fishery managers as a practical and economical measure to reduce sea turtle mortality in pelagic longline fisheries. Specifically, the effectiveness of 18/0 circle hooks has been evaluated with respect to reducing sea turtle interactions and maintaining swordfish and tuna catch rates. Individually, circle hooks and mackerel bait significantly reduced both loggerhead (*Caretta caretta*) and *leatherback (Dermochelys coriacea)* sea turtle bycatch *(*Watson *at al* 2005*).*

Setting longlines

Longline set depths can be critical to incidental sea turtle mortality. The depth at which longline gear are set and the length of leaders for individual hook lines from the main line affect both the takes and mortality of sea turtles. Arrangement of gear configuration and setting of the line such that the hooks remain active only at depths beyond the range of sea turtle interaction would reduce sea turtle mortalities. Shallower sets of longline gear are more likely to result in interactions between the turtles and the gear, since turtles are more likely to swim higher in the water column. Longer leaders can reduce sea turtle mortality. In addition, after hooking, by pelagic gear, line cutters can reduce sea turtle mortality by allowing the turtle to swim away rather than bringing the turtle onboard. Retrieval of longline gear earlier in the day and reducing soak time of hooks is also suggested.

Purse seine fishing and sea turtle interaction

Sea turtles are occasionally caught in purse seines in the tuna fishery. Most interactions occur when the turtles associate with floating objects (for the most part fish-aggregating devices (FADs), and are captured when the object is encircled; in other cases, the net, set around an unassociated school of tunas or a school associated with dolphins, may capture sea turtles that happen to be in the location. In these latter cases, the presence of tunas and turtles together may be influenced by oceanographic features such as fronts, but is essentially a chance event because turtles cannot swim fast enough to travel with tunas or dolphins. Once captured, the turtles may be released unharmed, injured, or dead. They can drown if they are entangled for a prolonged time and are unable to reach the surface to breathe. The actions to reduce sea turtle mortality in purse seines include: -

- Avoid encirclement of sea turtles to the extent practical.
- If encircled or entangled, take all possible measures to safely release sea turtles.
- For fish aggregating devices (FADs) that may entangle sea turtles, take necessary measures to monitor FADs and release entangled sea turtles, and recover these FADs when not in use.
- Conduct research and development of modified FADs to reduce and eliminate entanglement.
- Implementation of successful methodologies developed.

Gillnets and sea turtle interaction

Gill net fishery is the man stray of the traditional sector along the Indian coast. In Andhra Pradesh about 7,12,362 gillnets and 4,013 drift gillnets are being operated. (CMFRI census, 2002) Turtles become entangled in artisanal gill nets set inshore close to the nesting beaches and on the path of the sea turtle migration. On the high seas they get caught in massive drift nets. Rajagopalan (2001) reported that gillnets accounted for 76.8 percent of turtles landed or trapped along the Indian coast. Therefore, the crucial factor to be considered in planing conservation measures is the livelihood of coastal fishers.

the following are gear-technology approaches that have been shown to significantly reduce sea turtle catch rates in individual gillnet fisheries:

- Reducing net profile (vertical height; Eckert et al. 2008).

• Increasing tiedown length, or eliminating tiedowns (Price and Van Salisbury 2007).

• Placing shark-shaped silhouettes adjacent to the net (Wang et al. 2009);

• Illuminating portions of the net using green lightsticks (Wang et al. 2009).

In demersal gillnet fisheries, use of narrower (lower profile) nets is an effective and economically viable method for reducing sea turtle by-catch rates due to the combined effect of: The net being stiffer, thereby reducing the entanglement rate of turtles that encounter the gear, as sea turtles that do interact with the gear to ‘‘bounce out’’ and free themselves more readily than with conventional gear and the net being shorter, thereby reducing the proportion of the water column that is fished and so reducing the likelihood of turtles encountering the fishing gear.

Increasing tiedown length, or avoiding the use of tiedowns, has also help decrease turtle entanglement rates in demersal gillnets. In demersal gillnet fisheries, tiedowns are typically used to maximize the catch of demersal fish species. Tiedowns are lines that are shorter than the fishing height of the net and connect the float and lead lines at regular intervals along the entire length of the net. This net design creates a bag of slack webbing which aids in ‘‘entangling,’’ rather than ‘‘gilling,’’ demersal fish species. The shorter the length of tiedowns, the deeper the webbing pocket is. Unfortunately, this technique also poses an entanglement hazard to sea turtles that encounter the gear. Several studies in North Carolina’s flounder (Paralichthys lethostigma) gillnet fishery found that lower profile nets without tiedowns resulted in a significantly lower incidence of seaturtle entanglement, compared with traditional gillnets containing twice as much webbing (twice the number of meshes) and containing tiedowns regularly placed throughout the gear (Price and Van Salisbury 2007). Research has also demonstrated that entangled turtles have a higher rate of escape when longer tiedowns are used (Gearhart and Price 2003).

illuminating nets with green lightsticks attached to the net can reduce green sea turtle by-catch rates without adversely affecting the catch rate of target species when compared to control nets without illumination research in a Mexico demersal gillnet fishery (Wang et al. 2009). Incorporating a shark shape was also found to result in a significant reduction in sea turtle catch rates; however, this resulted in a large and significant reduction in the target species catch rate (Wang et al. 2009)

Aspects of gear design, materials and methods that affect turtle survivorship after interaction with gear is also limited. This information is fundamental to guiding further research and development of gear-technology approaches to by-catch. Mitigation. Unfortunately, Technological interventions in this case is scarce. Therefore, a dynamic spatial temporal restriction seems may be an alternative since turtles show a preference to specified area and seasons for migration and nesting. Once vulnerable areas are identifying, it should be possible to evolve and adopt suitable measures with active participation of the community. Research on the turtle mortality in relation to type of gillnet, depth of operation and time of operation would help in evolving a framework for conservation measures.

Fisheries management guidelines for fisheries activities and conservation and management of sea turtles.

FAO 2003 prepared to Guidelines offer guidance to the preparation of national or multilateral fisheries management activities and other measures allowing for the conservation and management of sea turtles. They apply to those marine areas and fisheries where interactions between fishing operations and sea turtles occur or are suspected to occur. They are global in scope but in their implementation national, subregional and regional diversity, including cultural and socio-economic differences, should be taken into account.

1. Fishing operations

A. Appropriate handling and release.

(i) In order to reduce injury and improve chances of survival:
(ii) Requirements for appropriate handling, including resuscitation or prompt release of all bycaught or incidentally caught (hooked or entangled) sea turtles.
(iii) Retention and use of necessary equipment for appropriate release of bycaught or incidentally caught sea turtles.

B. Coastal trawl

(i) In coastal shrimp trawl fisheries, promote the use of turtle excluder devices (TEDs) or other measures that are comparable in effectiveness in reducing sea turtle bycatch or incidental catch and mortality.
(ii) In other coastal trawl fisheries, collect data to identify sea turtle interactions and conduct where needed research on possible measures to reduce sea turtle bycatch or incidental catch and mortality.
(iii) Implementation of successful methodologies developed

C. Purse seine

(i) Avoid encirclement of sea turtles to the extent practical.
(ii) If encircled or entangled, take all possible measures to safely release sea turtles.
(iii) For fish aggregating devices (FADs) that may entangle sea turtles, take necessary measures to monitor FADs and release entangled sea turtles, and recover these FADs when not in use.

(iv) Conduct research and development of modified FADs to reduce and eliminate entanglement.
(v) Implementation of successful methodologies developed

D. Longline

(i) Development and implementation of appropriate combinations of hook design, type of bait, depth, gear specifications
(ii) Fishing practices in order to minimize bycatch or incidental catch and mortality of sea turtles.

Other fishery management stategies

(i) Spatial and temporal control of fishing, especially in locations and during periods of high concentration of sea turtles.
(ii) Effort management control especially if this is required for the conservation and management of target species or group of target species.
(iii) Development and implementation, to the extent possible, of net retention and recycling schemes to minimize the disposal of fishing gear and marine debris at sea, and to facilitate its retrieval where possible.

2. Research, monitoring and sharing of information

A. Collection of information and data, and research

(i) Collection of data and information on sea turtle interactions in all fisheries, directly or through relevant RFBs, regional sea turtle arrangements or other mechanisms.
(ii) Development of observer programmes in the fisheries that may have impacts on sea turtles where such programs are economically and practically feasible. In some cases, financial and technical support might be required.
(iii) Joint research with other states and/or the FAO and relevant RFBs.
(iv) Research on survival possibilities of released sea turtles and on areas and periods with high incidental catches.
(v) Research on socio-economic impacts of sea turtle conservation and management measures on fishers and fisheries industries and ways to improve communication.
(vi) Use of traditional knowledge of fishing communities about sea turtle conservation and management.

B. Information exchange

(i) Sharing and dissemination of data and research results, directly or through relevant RFBs, regional sea turtle arrangements or other mechanisms.
(ii) Cooperation to standardize data collection and research methodology, such as fishing gear and effort terminology, database development, estimation of sea turtle interaction rates, and time and area classification.

(i) C. Review of the effectiveness of measures

(i) Continuous assessment of the effectiveness of measures taken in accordance with these guidelines.

(ii) Review of the implementation and improvement of measures stipulated above.

3. Ensuring policy consistency

A. Maintaining consistency in management and conservation policy at national level, among relevant government agencies, including through inter-agency consultations, as well as at regional level.

B. Maintaining consistency and seeking harmonization of sea turtle management and conservation-related legislation at national, sub-regional and regional level.

4. Education and training

A. Preparation and distribution of information materials such as brochures, manuals, pamphlets and laminated instruction cards.

B. Organization of seminars for fishers and fisheries industries on:
   A. Nature of the sea turtle-fishery interaction problem
   B. Need to take mitigation measures
   C. Sea turtle's species identification
   D. Appropriate handling and treatment of bycaught or incidentally caught sea turtles
   E. Equipment to facilitate rapid and safe release
   F. Impacts of their operations on sea turtles
   G. Degree to which the measures that are requested or required to adopt will contribute to the conservation, management and recovery of sea turtle population.
   H. Impacts of mitigation measures on profitability and success of fishing operations
   I. Appropriate disposal of used fishing gear

C. Promotion of awareness of the general public of sea turtle conservation and management issues, by government as well as other organizations

5. Capacity building

A. Financial and technical support for implementation of these guidelines in developing countries.

B. Cooperation in research activities such as on status of sea turtle incidental catch in coastal and high seas fisheries and research at foraging, mating and nesting areas.

C. Establishment of a voluntary support fund.

D. Facilitation of technology transfer.

6. Socio-economic and cultural considerations

A. *Taking into account*:

(i) socio-economic aspects in implementing sea turtle conservation and management measures.
(ii) cultural aspects of sea turtles' interactions in fisheries as well as integration of cultural norms in sea turtle conservation and management efforts.
(iii) sea turtle conservation and management benefits to fishing and coastal communities, with particular reference to small-scale and artisanal fisheries.

B. Promotion of the active participation and, where possible, cooperation and engagement of fishing industries, fishing communities and other affected stakeholders.

C. Giving sufficient importance to participatory research and building upon indigenous and traditional knowledge of fisherfolk

C. Giving sufficient importance to participatory research and building upon indigenous and traditional knowledge of fisherfolk

These modifications in fishing methods significantly help in reducing the capture rate of sea turtles and potentially the post fishing mortality of those that were caught and did not negatively impact the primary target species catch. These mitigation measures have the potential to reduce mortality of sea turtles and other bycatch species worldwide. Better understanding of the links between sea turtles and fishing allows the design of conservation initiatives that reduce their interactions and thereby sea turtle mortality. Better understanding of these links leads, in part, to designing fishing gear, and adopting management practices and methods of fishing that reduce the takes and mortality of sea turtles.

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12. Advances in deep sea and oceanic fishing

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Introduction

Fisheries play a pivotal role in the economic development of all maritime nations. The fisheries sector contributes as foreign exchange earner, ensures nutritional security and generates employment opportunities. With absolute rights on the EEZ, India has also acquired the responsibility to conserve, develop and optimally exploit the marine resources up to 200 nautical miles off our coastline. According to Food and Agriculture Organization (FAO), Deepsea fisheries are those that take place at great depths and many deepsea fisheries take place in waters beyond national jurisdiction (such as the Exclusive Economic Zone [EEZ]), that is in the high seas. In recent years, the deep-sea fishery resources have become the iconic last frontier for the expansion and in forefront of marine fisheries. In general, marine living resources caught in the high seas always pose scientific and technical challenges. Worldwide a number of governmental and non-governmental organizations with mandates relating to conservation of the environment, biodiversity and management of fisheries have expressed concerns about the likely, known or feared consequences of deep-sea fishing in terms of its effects and impacts on target stocks, associated species and habitats. Fisheries play a pivotal role in the economic development of all maritime nations. The fisheries sector contributes as foreign exchange earner, ensures nutritional security and generates employment opportunities. Among the total world fish production India contributes more than 4 per cent. Even though the country unable to reach the annual per capita fish consumption of 11 kg /yr, the present per capita consumption is around 9 kg, it shows the need for an immediate additional nutritional requirement of the country. Indian marine fish harvest mostly centers around coastal waters up to 100 meters depth and about 90 per cent of the catch comes from up to 50 m. A recent revalidation of marine fisheries potential has shown that the fishing pressure on the stock in near shore waters has gone up considerably and signs of over exploitation of species is becoming increasingly evident and further increase in effort in the coastal sector would be detrimental to sustainable yield. The impact of undeterred mechanized trawling and purse seining has also caused resource depletion. Sustainable resources exploitation from this sector is still possible through regulatory management strategies and concerted policy efforts for different species and for different regions.Deep sea fishery over the years has undergone several changes like modernisation of fishing practices along with diversification, intensification and extension of fishing to new grounds and landing from incidental by catch to targeted commercial fishery. In India the coastal fishery sector is now facing challenges like the sustainability, resources conservation and management; therefore, there is an urgent need for looking forward the unexploited or least exploited resources so as to meet demand towards the nutritional security of the country as a whole.

The species composition of oceanic resources include Yellowfin tuna, Skipjack tuna, Bigeye

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tuna, Billfishes, Sharks, Barracuda, Dolphin fish, Wahoo, etc. From the species composition it is clear that the primary objective of exploring oceanic fishery should be to exploit quality Yellowfin tuna resources and complement this with skipjack tuna and other resources such as Bigeye tuna and Billfishes. India is still a small player in global tuna fisheries. Except the Lakshadweep group of Islands, there is hardly any organized tuna fishery in India. Synonymous with tuna fishing, the Lakshadweep Islands abound in skipjack followed by yellow fin. Fish aggregating devices such as 'payao' were introduced in Lakshadweep for increasing tuna catch and have performed well. Similarly, the Lakshadweep Administration is introducing larger fishing vessels for increasing tuna catches from its waters. Baitfish fishing also forms an important component of the pole and line tuna fishing of Lakshadweep and could become a constraint in future if not managed sustainably. In the Bay of Bengal, the Andaman and Nicobar Islands offer some of the best tuna fishing grounds in the Indian EEZ. However, due to lack of capacity and weak forward and backward linkages prevailing in the Islands, tuna resources from the Andaman and Nicobar waters have largely remained unexploited. Since the oceanic tunas are migratory in nature, the tunas that could have been caught by the Indian fleet in the Andaman and Nicobar waters mostly get harvested in the EEZs of the neighbouring countries or in the high seas by the fleet of the distant water fishing nations. Simultaneously, the small-scale fishing sector, especially off the coast of Visakhapatnam and in some coastal districts of southern Tamil Nadu has also ventured into tuna fishing. These initiatives include the targeting of Skipjack and Yellow fin tunas (particularly in Vishakapatnam) using troll line, hand line, gill nets and hook and line. In southern Tamil Nadu (Nagapattinam area), large floating devices are being developed to aggregate tuna and tuna-like species.

Fishing in the marine waters beyond national jurisdiction (the "high seas" covering 64% of the ocean's surface) is dominated by a small number of fishing countries, which reap most of the benefits of fishing this internationally shared area. The rationality of widespread high-seas fishing has been questioned because of its environmental impacts and uncertain economic profitability. Deep-sea bottom trawling can damage fragile habitats containing unique biodiversity including millenary deep-sea corals. Highly migratory species such as tuna and sharks that move between the high seas and countries' jurisdictional waters [exclusive economic zones (EEZs)] tend to be intensely fished and overexploited. Although the International Seafood Sustainability Foundation indicates that 57% of managed tuna stocks are considered to be at a healthy level of abundance, 13% are overfished, and even those that are not overfished show slight declines in biomass over time and may benefit from increases in biomass. Oceanic sharks, of which 44% are threatened, spend a great deal of time in the high seas, where shark fishing is largely unregulated and unmonitored. Here, we characterize the global high-seas fleet in detail and estimate the net economic benefit of high-seas fishing using (i) reconstructed estimates of the global fishing catch and its landed value, (ii) the costs of fishing based on satellite-inferred fishing effort and vessel characteristics, and (iii) estimates of government subsidies per country. We report high-seas fishing profits by fishing gear type, flag state, and Food and Agriculture Organization of the United Nations (FAO) region, with the goal of understanding whether fishing the high seas is economically rational. There are many fishing techniques to exploit deep sea resources of which Gill netting is a age old practice.

Gill Netting

Gillnetting, an age-old fishing practice in the world has shown a spectacular increase in operation in recent years. In recent times the following observations are made on the world gill net fishing:

- The drift: gill net fleet of the world act as curtains of death, land huge quantities of non-targeted species, prevent the salmon from reaching their native spawning sites, and also entangle, mutilate and drown thousands of marine mammals.

- Gill net fishing as a major threat to sea-life without curtailment of drift gill net fishing humanity will have little scope to protect its seas for future generations.

- Serious concern that over-exploitation of living marine resources in the high seas adjacent to the EEZ of coastal states is likely to have adverse impact and called for progressive reduction as well as ceasing further expansion of large-scale pelagic drift net fishing.

Drift netting consists of fishing nets set vertically in the water with buoyant floats along the top of the net, and a weighted lead line along the bottom. Fish and any other marine animals in the net zone are caught while swimming along, and fishermen later recover the drifting net. Oceanic drift gillnetting as a commercial enterprise is not in vogue in the Indian EEZ, but in the traditional sector a variety of large mesh drift gillnets are being operated by mechanise and non-mechanised crafts, aiming mainly to catch larger pelagics in the offshore waters up to 50-100 m. These gears have become more popular in view of easy maintenance and economy in operation and the number of these units has been increasing in recent years. According to WWF, the incidental catch of unwanted animals known as bycatch translates into one death every two minutes for small whales, dolphins and porpoises. The use of drift nets is one of the major sources of by-catch. This by-catch threatens 26 species of seabirds. Is also responsible for declining half of global shark catch and harms hundreds of thousands of sea turtles. In an attempt to control the negative impacts of drift nets, the United Nations in 1992 banned the use of drift nets longer than 2.5 kilometers. Drift nets became a popular commercial fishing method due to cost effectiveness, large amounts of fish are caught at once, maximizing the time and efforts of fishermen. The bigger the net, the bigger the catch. During the past two decades, drift nets and gill nets more generally have undergone a revival in their use, especially in traditional and modern small-scale fisheries. Such nets are relatively cheap and easy to use, principally because relatively low-powered vessels can be used to deploy them which make them fuel-efficient. International regulations are outdated, and the damage is still going on in high seas.

High-seas governance

Reducing bycatch would depend on enforcing international rules, like the ban on extra-long drift nets. Indeed, according to the Global Ocean Commission, "the existing high seas governance framework is weak, fragmented and poorly implemented.

Deep sea trawling

Deep-sea fish species are targeted globally by bottom trawling. The species captured are often characterized by longevity, low fecundity and slow growth making them vulnerable to overfishing. In addition, bottom trawling is known to remove vast amounts of non-target species, including habitat forming deep-sea corals and sponges. Therefore, bottom trawling poses a serious risk to deep-sea ecosystems, but the true extent of deep-sea fishery catches through history remains unknown. The landings from deep-sea fisheries are miniscule, contributing less than 0.5% to global fisheries landings. The fisheries were found to be overall under-reported by as much as 42%, leading to the removal of an estimated 25 million tons of deep-sea fish. The extension of bottom trawling to the deep-sea occurred in the second half of the twentieth century, prompted by technological advances and a decline in shallow water fisheries. The fisheries industry, particularly in Europe, North America, and the former Soviet Union, pushed into ever deeper water in search of more fish. In many cases, these fisheries were promulgated on the high seas where there were few. Many of those fisheries, especially those targeting seamounts have been shown to be "boom and bust" fisheries, and lasting from less than a decade to a couple of decades before they are no longer economically viable. The deep sea is an ecosystem different from that of shallower water. Here organisms, including fish, generally live for long times, have low fecundity, mature at older ages, and have lowered metabolism and slow growth. In addition, deep-sea fish may be more vulnerable to the fishery by aggregating on seamounts for mating or taking advantage of trapping of vertically migrating nekton by seamount topography. It is likely that deep-sea fisheries could easily and rapidly, over-exploit fish species living on seamounts and ridges, or along the continental slopes of the world. Fishing in the deep is difficult, and requires large vessels with very heavy gear in order to reach species living at depths of as much as 2,000 m. Deep-sea fishing vessels are often of 80–100 m length, weighing in at 2,000 gross tons or more. In some distant water fisheries, the vessel may be much larger and house crew and capabilities for processing and freezing the catch while at sea. Deep trawl gear is usually in the form of an otter trawl which uses metal "doors" that can weigh up to 5,000 kg in order to get the net to the bottom and keep the net mouth open while being pulled across the seafloor. The trawl can be very wide, with total distance including the sweeps, bridles and ground gear amounting to 80–200 m. The ground gear of a deep-sea trawl is equipped with steel bobbins and/or stiff rubber discs that are designed to allow the net to move over rough bottom without getting "hung up" . This equipment guarantees that bottom trawling is the most efficient fishing method in the deep-sea, but also the most destructive as it permanently removes the benthic habitats, typically comprising long-lived habitat-forming species, such as deep-sea corals and sponges.

Pelagic or mid-water trawling

Fish that live in the upper water column of the ocean are targeted by pelagic/ mid-water trawls. The funnel-shaped trawl nets are hauled by either one or two boats (pair trawls). Pelagic boats generally fish for a single species (unlike the demersal trawls). On very large vessels, fish such as herring and mackerel are pumped onboard the vessel through a large pipe placed in the end of the net. Smaller vessels bring nets onboard. Once captured, the fish is either kept chilled on board or processed and deep-frozen at sea.

Environmental summary

- **Habitat damage** - pelagic trawls don't come into contact with the seabed so are not associated with damage to marine habitat.

- **Bycatch of vulnerable species** - pelagic trawls may unintentionally catch vulnerable species. An example is pair trawls that target seabass in the English Channel. This fishery has been under scrutiny for catching dolphins as they trawl.

- **Discards** - pelagic trawling for a particular species can be associated with capture of non-target fish and other marine life and the accidental catch and discarding of juvenile commercial fish species can impact on these populations. However, bycatch levels are typically lower than in demersal trawls.

Trawl gear without any bottom contact during fishing is certainly not harmful to the bottom habitat. Trawling off-bottom is called pelagic trawling and is conducted in the water column anywhere from the surface to the vicinity of the bottom. Pelagic trawling is primarily used to exploit pelagic fish resources either in schools or in layers. However, some species are known to have seasonal and diurnal vertical migrations and are therefore available for both pelagic and bottom trawls. Catching such species with pelagic trawls when they are off-bottom is thus an option that will reduce the bottom impact significantly. There are several examples of pelagic trawling for species with both demersal and pelagic vertical distribution. In the North Atlantic a major pelagic trawl fishery has developed since 1975 for blue whiting. Prior to 1975 this resource was captured with bottom trawls in the North Sea. Until 1977 cod, haddock and saithe in the Barents Sea were captured with pelagic trawls as well as with bottom trawls. Poor size-selectivity and large catches of small-sized fish was the main reason for the introduction of a ban on pelagic trawling in the Barents Sea in 1977.Alaskan pollock was only captured with bottom trawls prior to 1990. Concerns about the bycatch of crabs and other ground fish species, such as Pacific halibut, initiated a switch to pelagic trawling for the pollock. In recent years, the size-selective properties of trawls have been improved with the introduction of new mesh configurations (square meshes, T-90 meshes and exit windows, etc.) and sorting grids. Pelagic trawl techniques have also become more efficient during the last two decades with the introduction of mega sized large mesh trawls and advanced instrumentation to monitor trawl performance.

Purse seining in high seas

A purse seine is a large wall of netting deployed around an entire area or school of fish. The seine has floats along the top line with a lead line threaded through rings along the bottom. Once a school of fish is located, a skiff encircles the school with the net. The lead line is then pulled in, "pursing" the net closed on the bottom, preventing fish from escaping by swimming downward. The catch is harvested by either hauling the net aboard or bringing it alongside the vessel.

- Purse seines can reach more than 6,500 ft (2,000 m) in length and 650 ft (200 m) in depth, varying in size according to the vessel, mesh size, and target species.
- Finding a school of fish is one of the most difficult steps of this fishing technique and include:
    - Natural cues such as a congregation of seabirds, ruffling of surface water and/or fast-moving groups of dolphins.
    - Helicopters scanning the water for natural cues from the air to direct boats toward schooling fish.
    - Using radar fish finders to help identify the exact location and size of a school.

Target Species

- Schooling pelagic fish of all sizes, from small sardines to large tunas.
- Squids

Risks to Sea Turtles

Purse seining is a non-selective fishing method that captures everything that it surrounds, including protected species. Sea turtles can be captured by a purse seine as it is set and then become entangled in the net mesh as it is hauled in. Entangled turtles may sustain injuries to their flippers and shells due to the force of the net as it is hauled. In a large catch, turtles' risk being crushed under the sheer weight of the tow. Captured turtles can be released alive if they are quickly retrieved and removed from the net.

Risks to Marine Mammals

Purse seines can easily encircle marine mammals along with target species as the net is set. Historically, dolphin pods were even used as a natural cue visually leading purse seiners toward areas of abundant schooling fish (called "setting on dolphins"). Once the netting has been set, encircled marine mammals cannot escape and can become entangled, injured, or stressed. Even with quick retrieval, marine mammals' sensitive bodies and internal organs cannot usually withstand the weight of the catch or the impact of being placed on the vessel.

Bycatch Reduction

Currently no regulations exist for minimizing bycatch of protected species in purse seine fisheries. Employing fisheries observers who scan the water prior to setting nets is the most effective way of minimizing incidental capture.

Squid jigging

Squids *are* most abundant cephalopods attracts hundreds of fishing vessels from around the world to international waters to take home catch. Squids is of high socio-economic importance to communities throughout the region, not just as a source of food security but for income as well. **Squid are migratory and always on the move.** Cephalopods play an important role in the ecology of the high seas act as a linkage between abundant mesopelagic fishes, crustaceans, sea birds and whales. Cephalopods are exclusively marine predators and voracious carnivores with very high metabolic and conversion rates. They feed on live prey throughout their life cycle. The commercially important cephalopods under the phylum Mollusca include nautilus, cuttlefish, octopus and squids. Squid jigging accounts for nearly 40 per cent of the world cephalopod catches followed by trawling, which contributes 25 per cent of the catch. Gillnets are also used for catching the squids, which accounts for nearly 10 per cent of the catch. Gears like shore seines, boat seines, hooks and lines and spearing are the popular methods to catch cephalopods. Cephalopods are considered as an important source of marine fishery resource and many of the species are exploited as bycatch by trawlers along the Indian coast and the fishery forms 4-5 per cent of the total marine fish landings. India government with the association of private trawlers conducted exploratory trawling for the cephalopod resources in the Indian EEZ since 1977-80s. Arabian Sea is considered as one of the richest fishing regions for *Sthenoteuthis oualaniensis*. The preliminary studies on the oceanic squids in the Arabian sea indicated that the area around Lakshadweep Islands is a major spawning grounds for oceanic squids (CMFRI, 2011). These species are known as the masters of the Arabian Seas due to its high abundance and large oceanic squids occupy and monopolise the trophic niche of apex predators in the Arabian Sea.

Fish aggregating devices (FADs) are traditionally used by the fishermen to attract and aggregate the fishes closer to the shore. Fishermen from Karnataka started FAD assisted cephalopod fishery in coastal waters of Karnataka. Coastal cephalopod resources in Indian are facing tremendous pressure due to fishing. The exploitation of untapped or under exploited oceanic squid resources from the Arabian Sea will reduce this fishing pressure taking into account the relative huge quantity of the unexploited resources. The total world catch of squids has increased steadily over several decades but there is now evidence in the FAO data that this has been followed by an apparent stabilization over the last ten years. Behind this recent overall stability, however, there has been considerable variation within species. Given the role of squids in marine ecosystems, there are good reasons to monitor the global catch in future and explore the reasons for its behaviour over time. It becomes clear that production has levelled off it should highlight the need for careful management of individual stocks in future and also the need to make maximum use of the catch to avoid waste and maximize the economic benefits from an industry which is reaching the limits of growth. The assessment of squid stocks and management of the fisheries is inconsistent regionally and there would be advantages in moving toward standardizing the approach, especially in the major fisheries. Less attention has been given to the role of squids as predators. They are key prey for vertebrate predators and have substantial seasonal impact on their own prey populations so unsustainable levels of exploitation will have impact through-out much of the food web. The role of squids in ecosystem change includes their response to change caused by overexploitation of ground fish stocks as well as their response to changes in other predator populations and to environmental variability on various timescales, including long-term climate change. An important scientific challenge for the future will be to discriminate between these interactions in order for fishery managers to respond appropriately to changes in squid stocks. It is advisable to use information on large-scale oceanographic processes in the management of the renewable resources including squids of these systems.

Fishing Methods

Cephalopods in general and squids in particular possess ecological and behavioral features that are quite similar to those of fishes. Many nektonic squids migrate in dense schools similar to those of pelagic fishes and fishing methods are common to both groups.

Trawls

Various types of fishing gear based on nets have been used for catching squids since the early days of exploitation. These include the various trap nets, set nets, and purse seines that have mainly been used in artisanal fisheries. The advent of motorized vessels in the early 20th century created opportunities for targeting large schools of pelagic and near bottom squids as well as fish. Trawlers use various types of the trawling gear (pelagic, semi-pelagic, and bottom) which are deployed during daytime to exploit the natural behavior of squids over the continental shelf as they aggregate near the seabed during daylight. The trawling gear used is essentially the same as that used for finfish. Pelagic trawls are used to catch squids near the bottom. Bottom trawls are used mainly to catch near-bottom aggregations of loliginid squids. The commercial otter trawl has two hydrovanes, known as otter boards or doors, one on each side of the net to spread the trawl horizontally. Special cables called bridles and sweeps connect the doors to the trawl wings. The movement of the cables through the water creates disturbance that is sensed by the fish lateral line, herding the fish close to the midline of the net. Unlike fish, squid use mainly vision for their orientation in the water column, and disturbance of water by the door cables has a lesser effect on their behavior in front of the trawl. In order to concentrate squid schools from a wide area into the wings of the trawl, polyvalent oval shaped doors are used. These scrape the seabed, creating clouds of silt that the squids attempt to avoid and so concentrate close to the midline of the net. This method has a negative impact on the sea floor as the trawl doors effectively plough the seabed and damage benthic communities. Trawlers use acoustic target-finding technology to locate aggregations of squids. However, squids provide weak acoustic targets because they lack a swim bladder so the technology has limited use where squid targets are mixed with fish possessing swim bladders. As trawls catch most individuals that are larger than the mesh size of the net, the total catch is very often mixed with the target species. The texture of squid skin is more delicate than that of fish, which is usually covered with scales, so in a mixed catch it becomes damaged and is sometimes completely removed from the body as a result of contact with knots in the mesh of the net and with other elements of the catch. In general, then, squid from trawlers is of inferior quality compared with the catch using methods such as jigging or trapping.

Jigging

Jigging for squid is less damaging to the marine environment and produces a more valuable product. This technology exploits the natural behavior of the squid which moves up in the water column toward the surface at night where they can then be attracted using lights toward the fishing vessel and the jigs. Many large-scale fisheries for both ommastrephid and loliginid squids employ jigging with lights. This method results in a higher value product where the squid can be sold whole because the process causes little or no damage to the skin. Although squid jigging vessels remain stationary in the water there is little or no saving on energy costs because the fuel used to generate the electricity to power the fishing lights is broadly equivalent to that consumed by trawling.

Modern squid jigging vessels have three elements:

- A large parachute drogue deployed as a sea anchor to hold the vessel still in the water.
- An array of incandescent lights to attract the squid at night when the squid naturally migrate upward to feed.
- Jigging machines which lower and raise the weighted lines to which are attached a series of colored or luminescent jigs—each of which is armed with an array of barbless hooks.

Driftnets

The Japanese squid driftnet fishery for neon flying squid, *O. bartramii*, was developed in the northwestern Pacific. From 1974 to 1978, the driftnet fishery operated off the Pacific coast of Japan but it conflicted with the jig fishery. The Japanese squid drift netters were converted from, or were also engaged in, other fisheries such as salmon driftnet fisheries, tuna fisheries, the Pacific saury fishery, squid jigging fisheries, distant water trawl fisheries, the North pacific longline, and gillnet fishery.

Deep Sea Long Lining

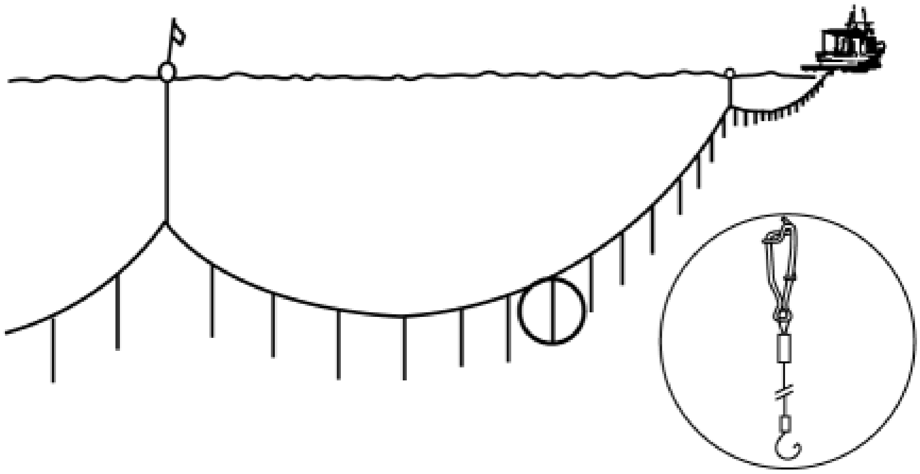
The name of "longline" comes from the length of the lines that are used. In broad terms, a longline consists of a mainline where many branch lines are attached. Each branch line has a baited hook at its end. Longlines are proven to be a good fishing method for catching large, high quality and high value fish. Therefore, it has become a popular method from 1980s. Longline gear is used all over the world, from small-scale fishing to modern mechanised longline operations. The longline is a very simple fishing gear, but there are many variations in gear construction, fishing method and fishing strategy. The high fuel consumption of large-scale fishing has made the fishermen adopt low energy fishing methods. Trawl fishing is very costly in terms of fuel and not environmentally friendly. Longline fishing, on the other hand, does not require much fuel and is environmentally friendly. In order to protect fish resources, trawl and purse seine fishing are not permitted in inshore seas, only in offshore and in open seas, and small-scale fishing is widely practiced in inshore seas. Most of the developing nations are trying to find solutions to increase the catch amount without using trawl and purse seine fishing in inshore waters. One solution is developing longline fishing because it secures sustainable catching with less fuel consumption in inshore areas and protects fish resources. The proportion of crafts engaged in long lining is increasing every year. In the past fishermen mostly used the hand line but nowadays longline fishing is increasing. The vessels used for longline are medium-sized with 120-400 HP engines and small vessels with 14-28 HP engines. The structure of the vessels has been altered for doing small-scale fishing like longline. There are some difficulties in doing longline fishing because it has not been practiced widely in the past. Squid and herring are mostly used for bait to catch demersal and semi pelagic fish. The bait size used in bottom set longline is based on fishermen's experience. Baiting is done by hand and hauling is mostly done by powered haulers. Longline fishing in Indian waters is in its initial stages and problems remain to be solved. The technical information on longline has not yet been widely introduced to the relevant people. Scientific fishing methods are not widely used and the mechanisation of longline is in its infancy. Fishermen use different sizes of bait according to their experience. This may be one of the reasons for the decreasing catch rate. A good understanding on how to study different bait sizes is therefore very important. In longline fishing, several factors such as the hook, bait, branch line and mainline affect catch ability and selectivity.

Classification of Longlines

Based on the structure and fishing method, longlines are classified into four categories: drift longline, bottom set longline, vertical longline and bottom vertical longline (Hameed and Boopendranath 2000). In some cases, longline is grouped into two categories: surface longline and bottom longline, but this categorisation is based on the same principles as the first.

What is long lining?

longline fishing uses a long mainline made of mostly nylon monofilament to which are attached hundreds or thousands of branchlines, each with a single baited hook. The mainline can be from 5 to 100 nm long. The line is suspended in the water by floatlines attached to floats, which may have flagpoles, lights, or radio beacons. Longlines are usually set and hauled once daily and are allowed to drift freely, or soak, for several hours while fishing. Longlines are set, either by hand or mechanically, while the boat steams away from the line and are usually hauled mechanically while the boat steams toward the line. The species targeted are tunas and some billfish.



Structure of Longline

Target Species

The main target species of oceanic longline fishing are tunas and billfish, while other species including sharks can also is an important component of the catch. The catches of long line can be divided into three distinct categories: target, byproduct and by-catch. Tunas are by far the most important target species for longlining. The highest value species are bluefin tuna, followed by bigeye tuna, yellowfin tuna, and albacore tuna, in that order. Some billfish are also targeted, with broadbill swordfish being the most important, followed by striped marlin.

Bigeye tuna:

Bigeye tuna are the most valuable species caught in the longlines and are found throughout the tropical and temperate waters in Pacific, Atlantic and Indian oceans. Fishermen targeting bigeye tuna set their lines deep because bigeye are often associated with the thermocline , which is found between 100 and 350 m, depending on the area and time of year. Bigeye tuna can be caught all year round in equatorial waters but are more seasonal in higher latitudes. The best bigeye catches are usually in the winter months. The most marketable bigeye tuna are those weighing 40 kg or more. Bigeye tuna are usually marketed as fresh chilled fish for sashimi.

Yellowfin tuna:

Yellowfin tuna are also found throughout the tropical and temperate waters of Pacific, Atlantic and Indian oceans, but the stocks change as per the oceans. Although they can be caught in deeper water, longline caught yellowfin are usually taken in water from near the surface down to 250 m above the thermocline. This layer of water is called the mixed and intermediate layer. The preferred temperature range for yellowfin tuna is 18° to 28°C, which roughly corresponds to temperatures found in the mixed and intermediate layer. The best season for yellowfin tuna is in the spring and summer months. The most marketable yellowfin tuna are those that weigh

30 kg or more. Yellowfin are usually sold as fresh chilled fish for sashimi or to be used in cooking. Yellowfin is second to bigeye as a sashimi fish in quality and value.

Albacore tuna:

Albacare tuna are also found throughout the tropical and temperate waters of Pacific, Atlantic and Indian oceans. These fish are schooling fish and are caught seasonally, in the summer and autumn months, at the surface by troll boats, and are smaller than longline caught albacore. Larger fish are caught by longline in deep tropical and subtropical waters down to the depth of the thermocline. Depth and temperature ranges for longline caught albacore are similar to those for bigeye tuna. The season for longline albacore is not as apparent as for other tunas — autumn months in some locations, all year round with peaks in summer and in autumn and winter in other locations, and autumn and winter months in other areas. Longline caught albacore range from 15 to 20 kg and are sold frozen whole to canneries, fresh to export markets, or as frozen quarter-loins.

Striped marlin:

Striped marlins are found throughout the tropical and temperate of Pacific, Atlantic and Indian Oceans. They are usually found in the upper mixed layer or near the surface. In fact, longline caught striped marlin are most often caught on the branchlines nearest the floats, the shallowest branchlines. They are not usually the main target species of longliners, but are caught in association with yellowfin tuna sets. The preferred surface temperature range for striped marlin is 20° to 23°C, although they can also be found in temperatures ranging from 15°to 26°C. The usual size range of striped marlin is 60 to 120 kg, although specimens up to 190 kg have been caught.

Byproducts and By-catch of longlining:

Byproduct and by are species that are caught incidentally (not targeted) during longline fishing, that have a commercial value and are retained for sale. These species include opah, black marlin, Indo-Pacific blue marlin, shortbill spearfish, sailfish, skipjack tuna, mahi mahi, wahoo, pomfret, escolar and barracuda, amongst others. A range of shark species are also taken as byproduct, although they are mainly prized for their fins (finning is probably going to be phased out as more and more countries are adopting a policy where the entire shark must be retained). Black marlin, Indo-Pacific blue marlin, sailfish, skipjack tuna, mahi mahi and wahoo are distributed throughout the subtropical and tropical Pacific Ocean and are caught near the surface on the shallowest hooks in a set, near the floats. Conditions for catching these species are similar to conditions for catching yellowfin. Byproduct species such as pomfret, escolar and opah are usually found in deeper waters and are associated with bigeye catches. The most common species of shark taken by longlining include the blue shark, oceanic white tip shark, short-finned mako shark, silky shark, thresher shark and tiger shark. These are all pelagic or oceanic sharks. Sharks are mainly caught on the shallower set hooks during normal tuna longlining activity.

By-catch:

Bycatch are the unwanted species that are taken incidentally during longlining, and are discarded as they have no commercial value. These species include snake mackerel, lancetfish, pelagic rays, seabirds and sea turtles, amongst others. Snake mackerel, lancetfish and pelagic rays can be taken at various depths on a longline, and are not really associated with a particular type of longline set. The fish are generally small in size. Seabirds, such as albatross, and sea turtles are sometimes caught on longlines. The seabirds attack the baits on the gear as it is being set, while the sea turtles are taken on the shallow hooks, generally near the floatline. The catch of seabirds and sea turtles by longliners has become an environmental issue as the animals are protected. This is an area of concern to all longline fishermen. Another form of bycatch are fish, both target and byproduct species, that have been damaged by sharks or toothed whales. In some cases, shark damaged fish may be retained for crew consumption or sale if the damage is limited. However, when toothed whales take fish, they only leave the heads, and these are discarded.

Bait used in longline fishing

Bait used for longline fishing is usually frozen whole finfish such as sardines, saury, or mackerel and scads. Frozen whole squid is often used for tuna longlining but is more important as bait for swordfish. Live milkfish is also used for tuna longlining. The average bait weighs about 80 to 100 g. If the bait is much bigger than 120 g it is likely that some target fish will be missed. The principle of line fishing is to lure fish to bite the bait. Therefore, bait is one of the most important factors in line fishing. The catch rate depends to a large extent on bait type, quality and size (Bach *et al*. 2000). Fishermen use different types of bait from their experience accumulated over the years. The type of bait is chosen with regard to the target species. Bait quality is one of the important factors, which affect the catch rate. Bait must also be suitable to the target species. What attracts the fish is the odour from the bait. As the odour gets stronger, the more it attracts fish. The quality of bait is also measured by how well it remains on the hook. In addition to the attractiveness of the smell and taste stimuli, the efficiency of bait is determined by its physical strength and ability to remain on the hook throughout the soaking time. The bait loss is more important for hooks on the bottom. Bait size is also an important factor affecting the fish size and catch rate. As bait in mid-water is more easily seen than bait on the seabed, the effects of bait size are more pronounced for pelagic or semi pelagic longline than for bottom longline. The bait size also affects the size of the fish caught, as small fish prefer small size prey because of their mouth size and ability to bite and handle the prey.

Bottom set longline

Bottom set longlines operate close to the sea bottom for demersal species such as shark, sea beams, sea bass, goupers, snapper, cod, haddock, halibut, hake and flat fish. As the bottom longlines are set near the sea bottom, they are easily damaged by obstacles on the bottom. When using bottom longlines, the ground must be fairly regular since rocks or corals may entangle the lines and break them. Where muddy bottoms are found, the longlines are not set to remain on the bottom and are held off the seabed by floats. They can be set so that the bait is suspended at any desired distance from the bottom. In bottom longline fishing, the main concern is the selection of optimum branch lines because of the character of the fishing operation. The bottom set longlines which have the branch lines set at wider spacing catch fish better than those with the branch lines set more closely together, and they also need less bait for the same area. The length of the branch line must be selected correctly. The branch line cannot be too short because short branch lines are less effective than long branchlines. The length of the branch line is related to the hooking space and the free space of the vessel used in longline fishing. The branch lines are knotted to the mainline. They can also be connected to the mainline by using removal clips or swivels. Using swivels has many advantages in handling. The branch lines can be easily changed and stored separately and also the distance between branch lines on the mainline can be adjusted whenever it is needed. It also has the advantage in eliminating entanglements of the branch lines, thus reducing the labour of gear handling. Branch lines are mostly made of monofilament and multifilament. In some longline fisheries, particularly for catching different sharks, branch lines made of steel wire or chain are used because fibre branch lines are easily cut by the sharp teeth. Bottom longline fishing is mostly carried out at depths from 100 to 800 m. The longline fleets are set on the bottom with anchors, buoy lines, buoys and/or marker buoys at either end. The anchor is made of stone, steel, lead or chain with a weight from 5-10 kg up to 80 kg. The purpose of buoys is to keep the gear in a certain position with anchor. It is made of synthetic fibre with different buoyancies. The buoy line is a rope somewhat stronger than the mainline, because it must have the high strain that is often needed to pull the anchor. In the middle, buoys with buoy lines and anchors are also used in order to save time and prevent the risk of losing gear if the mainline breaks during hauling. In case the line breaks, instead of moving to the end buoy, which might be far away, the middle buoy which is close to the vessel is picked up and the hauling is done continuously after short time. The purpose of the marker buoy is to mark the ends of the longline fleet so that fishermen can easily find the longline from a distance. It consists of a pole (3-4 m long) and a weight at the bottom end to keep it floating in an upright position. Marker buoys usually carry one or two flags at the top end in order to make it more visible and a battery-light package or radar- light reflector in the marker buoy is used to identify the gear easily in darkness. In addition to the marker buoy, there are normally one or more surface floats, the main function of which is to keep the strain off the buoy line. The amount of lines depends on the capacity of the vessel, topography of the bottom, and the distribution and density of fish. Fishing is done by setting in stern, soaking, and hauling in starboard and handling gear. Before setting, baiting is done by auto baiting machines on boat or manually on land. Soaking times are different depending on the fishing operation, normally two to three hours. Hauling is done by powered machines in the starboard. Different methods are used for storing longlines. In auto longline fishing, hooks with the mainline and branch line hang on racks. Basket, tubes and wooden or plastics boxes are used for keeping hooks with branch lines.

Drift longline and Pelagic longline:

Drift longline is operated close to the surface in middle water layers for pelagic fishes such as tuna, marlin, billfish, mackerel and shark. The fishing method is similar to the bottom set longline. The setting work is done from the stern. The speed of the vessel in setting differs according to the fishing conditions, but is normally around 5-6 knots. At first, marker buoys with flags, radio buoys and light buoys are thrown in and the mainline is released. The marker buoy, light buoys and radio buoys are connected at proper intervals. In case of auto line, hooks are baited when the mainline is released. After setting, the vessel stays for six hours near the line. In hauling, the line is hauled by a powered hauler and when the branch line comes onboard the fish is removed. For traditional drift longlines, the mainline carrying the branch lines is coiled and kept in a basket. In modern large-scale drift longline, mainline is continuously pulled and kept on a powered reel or rack with branch lines. There are some cases that on hauling branch lines are removed from the mainline and kept separately. But nowadays lines with branch lines are usually kept on racks after hauling. To locate the potential fishing ground and to position the line in deep seas, it is important to know the correlation between fish distribution and sea surface temperature or the thermocline. Distribution of fish is determined by temperature and feed organisms. Thermocline is the temperature continuity layer where temperature changes rapidly with depth, between mixed surface waters and cooler deeper waters. Fish like tuna are generally found in the thermocline layer. The swimming layer of the yellow fin tuna and albacore is in the mixed layer and thermocline. Big eye tuna occupies lower layers of the thermocline and the cooler waters below. Information on the swimming layer of target fishes and their association with the thermocline is used by fishermen for fishing the target species. Sea surface temperature and ocean colour charts are used to locate potential fishing grounds based on the temperature preference regimes of target species and the aggregation of feed organisms in the thermal front. The most common drift longline in fisheries is the tuna longline. The tuna longline was introduced by Japanese fishermen about 300 years ago and they have been a leading nation in terms of longline fisheries along with China and Taiwan. The tuna longline, like most of other longlines consists of many sets. Each set ranges from 150-400 m in length. Typical branch lines for tuna longline consist of three sections and each branch line is attached with a special snap-on metal clip to the mainline. Each set is stored in a basket. Japanese fishing boats, ranging from 200 to 800 gross tonnages in size, usually carry 350- 400 baskets of longline. The tuna longline is not only an effective fishing method but also a very labour intensive one. Mechanisation and automation for both bottom and drift longline are successfully under way. While setting, the hooks are baited by drawing them through an automatic machine. Mechanical hydraulic line haulers are now widely used in drift longline fishing. This system includes de-hooking of fish, twist removal of branch lines, hook cleaning and handling lines. This has decreased the manpower required dramatically.

Vertical longline

Vertical longline is used to catch fish with a wide vertical distribution. Vertical longline is effective on steep shelves. Vertical longline is used in deep waters up to 1,200 m and in shallow areas having rough bottom conditions or in areas where fish aggregating devices are deployed. Gear construction has a little difference to drift longline. It consists of a single line with a float at one end and a weight at the other. The mainline extending across the vertical range of the swimming layer of the target species is attached to the buoy line with a swivel. Branch lines are attached to the mainline through three way swivels or snap clips, at intervals of around 2 m. The mainline is set vertically with the upper end joined to a large float and flagpoles, and the lower end is provided with a sinker. Branch lines are attached at approximate intervals to the mainline. The fishing operation is similar to drift longline. When the vessel arrives at the fishing ground, the anchor, marker buoy and radio buoy with the connected end mainline are thrown overboard. The line is set over the stern when the vessel moves ahead. The hooks are baited before setting the line. After soaking for a period, the lines are hauled up using a line hauler. The soaking time depends on fish distribution and density. Fishes are removed when the branch lines come up, mainlines and branch lines are arranged and stored, and accessories are removed and stored. Bottom vertical longline combines the properties of the bottom set longline and vertical longline, using their advantages. Many hooks are attached at suitable intervals less than 2 m by polyamide monofilament lines less than a meter in length to the branch lines. Branch lines are designed to be directed vertically during operation by adding floats at the top and sinkers at the bottom end. Branch lines are hung from the mainline by means of snap clips at interval of 20-25 m. The mainline is positioned at an appropriate height from the bottom by adjusting the buoyancy. When the mainline does not touch the ground the gear is particularly suitable for rough grounds.

Pelagic longline

Pelagic longline is normally not anchored but drifts freely in the sea. Pelagic longlines are mainly used in high seas longline fisheries for pelagic species such as sword fish, tuna, shark and salmon, but are also in coastal waters for species such as haddock during periods when the fish are feeding on pelagic prey. The fishing operation is similar to drift longline. Between the ends (marker) buoys, the mainline is suspended in the sea by floats attached at intervals. Sometimes the branch lines are weighted, but this method usually relies on the mainline sinking under its own weight to get to the required depth.

What are the problems in longline fishing?

Declining sea turtle stocks:

Sea turtle populations are declining worldwide due to human activities including: destruction or disturbance of nesting beaches; hunting for food and sale; and incidental catches related to some fishing activities such as trawling, gillnetting, purse seining and tuna longlining.

Perceived overfishing:

There is worldwide concern about the catch and use of pelagic sharks and, to a lesser extent, marlins and other pelagic fish species by longline vessels. Some concerns are related to a belief that these species are being overfished.

Seabird interactions:

The incidental take of seabirds by longline vessels (both pelagic and demersal or bottom-set) has been widely publicised, although this mainly occurs with albatross in higher latitudes.

What can be done to make longline fishing sustainable?

- Minimizing the incidental catch of unwanted bycatch species. Keeping good data in logbooks on all fishing activities, including the recording of byproduct and bycatch taken or interactions with protected species.
- Setting pelagic longline gear deeper than 100 m will reduce the incidental catch of many bycatch species (especially sea turtles).
- Setting deep, using a line setter, puts the bait in the zone where catches of albacore and bigeye (target species) will be maximised.
- Not using squid for bait on shallow-set hooks (those closest to the float and floatline) will lessen the chance of hooking sea turtles, as this is a favourite food of theirs.
- Not using a branchline under the float to target sharks.
- Setting pelagic longlines at least 12 nm from a reef or island, and ensuring they drift offshore, will minimise interactions with reef sharks (not pelagic sharks) and some turtle species, as they do not venture far from the reef.
- Using monofilament leaders (not wire) directly onto the hook will allow sharks to bite off the hook and escape.
- The bycatch of sea turtles by pelagic longlining is an issue of great concern. If a turtle is caught, steps should be taken to give it the best possible chance of survival.

Avoiding seabirds and bait loss

The issue of tuna longline gear interacting with seabirds, causing incidental takes, is an issue in some regions in longline fishing. There is a problem though at times with bait loss through seabirds attacking baited hooks as they are set. In areas where seabird interactions have occurred, mitigation measures have been developed and introduced. These measures also work to reduce bait loss, by making it difficult for the seabirds to get to the baited hooks, or getting the baited hooks to sink faster. Setting tuna longline gear at night is by far the simplest and easiest way to avoid bait loss to seabirds, as most seabirds are day feeders. However, in some fisheries the setting time is dictated by the main feeding time of the target species and night setting of the gear may result in lower catch rates.

Depredation by toothed whales

'Depredation' is the term used when unwanted species such as cetaceans or sharks consume hooked fish, while predation refers to one species preying on another. Toothed whales sometimes attack and eat tuna and swordfish that are caught on longlines. When a pod of these whales finds a longline with fish, they follow the line eating everything except the head of the hooked fish. Some dolphin species have been associated with the loss of bait from longline gear. Some whales have interacted with the longline gear itself and become caught, putting the whale at risk and damaging the gear. Given there are no foolproof mitigation measures available at present, the following measures can avoid or minimise the chance of interactions or depredation.

- Reducing vessel noise, possibly through vessel design.
- Managing gear noise through its operation (turn off echo sounders when not in use, reduce noise of deck machinery, propeller noise etc.).
- Considering changes to gear and setting and hauling practices.
- Considering changing fishing areas and fishing seasons.
- Avoiding areas where cetaceans are known to congregate.
- If cetaceans are sighted during the set, discontinue the set, haul the line, and move to another location.
- Use acoustic equipment to try to locate and subsequently avoid cetaceans.
- Avoiding discarding of offal and used bait in the vicinity of fishing locations.

Concluding remarks

Longlining is one of the main fishing methods that holds potential for economic development in many countries and territories. The method targets the larger, deeper swimming tunas and other oceanic resources that command high prices in export markets if they are handled carefully and quality is maintained throughout the catching, processing and exporting processes. The costs for local operators to set up a longlining operation are high, but the potential returns are also great. While promoting longline fishing focus should be on sustainable and responsible fishing practices. longlining has 1.5 times more advantages than trawl and fewer drawbacks. However, it should be noted that longline fishing has the clear drawback of needing to use additional biological resources, ie. squid, fish, shellfish, etc, as bait for its hooks. This negative characteristic of longline fishing, however, is compensated for by the much more sparing fishing qualities it has in comparison with other fishing methods. Despite the few drawbacks of longline fishing, its advantages over other fishing methods are very clear. The large-scale development of the sustainable longline fishery is one of the means of optimizing the exploitation of tuna and other oceanic resources. At the same time, it is necessary to state that the development of the longline fishery must not only be aimed at increasing the size of the fleet, but also at increasing the working efficiency of existing vessels. Tunas and other oceanic resources can be caught very effectively using the longline, but remain inaccessible to the bottom trawl which is the most common fishing method. For promoting longline, it will be necessary to avoid shifting preference over to longlines entirely. It is should be borne in mind that some stocks of fish, bottom resources such as shrimps are difficult for the longline to access and their exploitation is only possible using trawl fishing gears. Therefore, it is essential to ensure that only the combined use of these fishing gears will allow for the optimal utilisation of the all the resources. There should be a rational distribution of fishing efforts according to fishing areas and seasons and the taking into account the various biological peculiarities of the fish being exploited

Although the environmental impacts of fishing on the high seas are well studied, the lack of transparency and data has precluded reliable estimates of the economic costs and benefits of high-seas fishing. Fisheries data suggest that fish catch in this vast area amounted to around 6% of global catch and 8% of the global fishing revenue in 2014 (see www.seaaroundus.org/data/#/global). However, the high level of secrecy around distant-water fishing has impeded the calculation of fishing effort and associated costs. Nevertheless, recent technological developments in machine learning and satellite data now allow us to obtain a far more accurate picture of fishing effort across the globe at the level of individual vessels (*9*). This capability provides a more transparent and novel method to examine high-seas fisheries and answer key questions such as whether fishing in the high seas is profitable and whether government subsidies enable current levels of fishing.

13. Innovative techniques in seafood processing

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Introduction

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

Benefits of Processing

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

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- Modern food processing also improves the quality of living by way of healthy foods developed for special people who are allergic to certain ingredients, diabetic etc., who cannot consume some common food elements
- Food processing can also bring nutritional and food security
- Provides potential for export to fetch foreign exchange

Aim of Preservation/ Processing

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

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

Live Fishery Products

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

Transportation of crab in live condition

Chilled Fishery Products

Chilling is an effective method of maintaining the freshness of fish products. This normally involves keeping fishes in melting ice or slurry ice to maintain the fish temperature around 1- 4 ºC, which delays the enzymatic action and microbial activity, thereby extending the shelf life of the products. Traditionally, chilling is carried out using melting ice, either flake ice or crushed block ice. Of late, slurry ice has been introduced for chilling. A wide range of fish and shellfish products varying from whole, headless, peeled gutted, headless gutted fish, fillets, steaks, loins, cubes can be preserved by chilling. Shelf life of fishes from different environment has been studied by the Division extensively. Shelf life of 12-15 days has been achieved for seerfish and black pomfret. Indian Mackerel and Indian oil sardine had very short shelf life in ice (3-7 days), due torancidity and belly bursting. Tilapia from freshwater and brackishwater showed significant difference in shelf life when stored in ice. The former kept longer (14-15 days) than latter (8-10 days).

Frozen Fishery Products

Freezing is an age old practice to retain the quality and freshness of fishery products for a long time. This involves the conversion of water present in fishery products to ice i.e., a phase change from liquid to solid phase takes place in freezing. This retards the microbial and enzymatic action by reducing the water available for their action. This involves exposing fish products to very low temperature (<-35^{0}C) to enable freezing of free water and maintained at -18^{0}C till it is consumed. Plate freezing, air blast freezing, cryogenic freezing and individual quick freezing are the methods adopted by the industry to preserve food products.

Canning

Canning is a method of food preservation in which preservation is achieved by the destruction of micro-organisms by the application of heat of food packed in a sealed container. Since the canned foods are sufficiently cooked products and free from micro-organisms, they offer consumer safety besides being ready to consume. Canning has the unique distinction of being an invention in the field of food processing/ preservation whereas all other methods can be considered as adaptation of natural processes or their modifications. Because of their very long shelf life and ready to consume feature canned products have become very popular and a variety of food stuffs, both plant and animal origin and their combinations are produced and distributed.

However, the fish canning industry in India is declining due to the high cost of cans. Recent innovations like polymer coated Tin Free Steel (TFS) cans provide a cheaper alternative. Studies conducted at CIFT showed that polyester-coated TFS cans are used for processing ready to serve fish products, which can be stored at room temperature for long periods. The industry can utilize these cans for processing ready to eat fish and shell fish products for both domestic and export markets. This will help in reviving the canning industry in India.

Unit Operations in a canning process are:

1. Selection and preparation of raw material.
2. Pre-cooking / blanching
3. Filling in to containers.
4. Addition of liquid medium
5. Exhausting
6. Seaming
7. Heat Processing / Retorting
8. Cooling
9. Drying, warehousing, labelling and casing

Dried and Salted Fishery Products

Drying is probably one of the oldest methods of food preservation. It consists of removal of water to a final desired concentration, which in turn reduces the water activity of the product, thereby assuring microbial stability and extended shelf-life of the product. In some cases, common table salt (Sodium chloride) is also used to prolong the shelf life of fish. Salt absorbs much of the water in the food and makes it difficult for micro-organisms to survive.

Dried fish and shellfish products prepared hygienically

Some commercially important dried products

Masmin

It is the main smoked dried fish product of the Lakshadweep islands. It is prepared from skipjack tuna. The meat is boiled in seawater and alternately dried and smoked till the characteristic flavour and colour is got. The finished product is a hard-smoked and hard dried one with a shelf life of more than a year

Dried Squid

Fresh squid is used for the producing dried squid. The squid is whole cleaned, slit open, dipped in salt solution and washed in clean water. It is dried on ropes, hung by the anterior side to a moisture level of 18%. The mantle is stretched and kept flat by passing through rollers.

Dried Jelly Fish

Both unsalted and salted dried jellyfish are produced for export. The salted jellyfish has final moisture content of 60% and unsalted about 20%. They are graded based on the size of the umbrellas.

Dried Bombay duck

Fresh Bombay duck is gutted and washed thoroughly. The fish is then dried on a scaffold by interlocking the jaws of two fishes. The head and fins are removed and it is split open, longitudinally. A dip treatment in 1% brine for 20 minutes is given and the fish is dried again on mesh trays to moisture content of about 16- 17 %. It is then flattened out in rollers and trimmed to required shape. The product is again dried until a moisture content of 10% is reached.

Smoked Fishery Products

Smoking is one of the most widely used traditional fish processing methods employed in many countries to preserve fish. The preservation effect of the smoke is a result of drying of the product during the smoking as well as due to smoke particle absorption into the flesh. The smoke particles, mainly phenolic compounds, carbonyl and organic acids, being absorbed by the product, inhibit bacterial growth on the surface of the product. The smoke particles also have a positive effect on the taste and colour of the product and in many instances, smoking is normally practiced to improve these sensory characteristics.

Hot and liquid smoked fish chunks and masmin chunks

Battered and Breaded Products

The most prominent among the group of value-added products is the battered and breaded products processed out of a variety of fish and shellfish. Battered and breaded products offer a ‘convenience’ food widely valued by the consumer. These are products, which receive a coat or two each of a batter followed by coating with breadcrumbs, thus increasing the bulk and reducing the cost element. The pick-up of coating can be increased by adjusting the consistency of the batter or by repeating the coating process. By convention, such products should have a minimum fish component of 50%. Coated products viz., fish fingers, squid rings, cuttlefish balls, fish balls and prawn burgers form one of the major fish and shellfish-based items of trade by the ASEAN countries (Chang et al., 1996).

The production of battered and breaded fish products involves several stages. The method varies with the type of products and pickup desired. In most cases it involves seven steps. They are portioning/forming, pre-dusting, battering, breading, pre-frying, freezing and, packaging and cold storage. The first commercially successful coated product is ‘fish finger; or ‘fish stick’. Later several other products particularly the coated fish fillet, fish portions, fish cakes, fish medallions, fish nuggets, breaded oysters and scallops, crab balls, fish balls, coated shrimp products, coated squid rings etc. became prominent in most of the developed countries with the advent of the fast-food trade. The present-day production of coated seafood items involves fully automated batter and breading lines which start from portioning and end with appropriate packaging of the product. A variety of battered and breaded products can be prepared from shrimp, squid, clams, fish fillets, minced meat from low-cost fish etc. A brief profile of some important battered and breaded products is given below.

Fish finger or Fish portion

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

Shrimp products

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

Fish fillets

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

Squid products

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

Clam and other related products

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

Fish cutlet

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

Fish balls

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

Crab claw balls

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

Fish Mince and Mince Based Products

Mechanically deboned fish meat is termed as fish mince. Fish mince is more susceptible to quality deterioration than the intact muscle tissue since mincing operation cause disruption of tissue and exposure of flesh to air, which accelerates lipid oxidation and autolysis. The quality of the mince is dependent on the species, season, handling and processing methods. Also, low bone content in the mince (01-0.4%) is desirable for better functional and sensory properties. Depending on the type of raw material, fish mince can have a frozen storage life up to 6 months without any appreciable quality deterioration. Generally minced fish is frozen as 1-2 kg blocks at -40 ^{0}C in plate freezers and stored in cold store at -18 ^{0} C.

Surimi

Surimi is stabilized myofibrillar protein obtained from mechanically deboned flesh that is washed with water and blended with cryoprotectants. Washing not only removes fat and undesirable matters such as blood, pigments and odoriferous substances but also increases the concentration of myofibrillar protein, the content of which improves the gel strength and elasticity of the product. This property can be made use of in developing a variety of fabricated products like shellfish analogues. India produces about 40.000 MT of surimi per annum ,70% of which comes from thread fin bream.

Kneaded products

Several kneaded products like kamaboko, chikuwa, hampen, fish ham and sausage are processed using surimi incorporating other ingredients. The ingredients used in most of these preparations are identical; however, the classification is principally based on the manufacturing process involved. The ingredients employed other than surimi include salt, monosodium glutamate, sugar, starch, egg white, polyphosphate and water. The method of processing all these products involves grinding together of the various ingredients to a fine paste and some sort of heat treatment at some stage.

Fiberized products

Fiberized products are in great demand among the surimi based imitation shellfish products. The ingredients used in the formulation of fibreized products includes, besides surimi, salt, starch, egg white, shellfish flavour, flavour enhancers and water. All the ingredients are thoroughly mixed and ground to a paste. The paste is extruded in sheet on the conveyor belt and is heat treated using gas and steam for partial setting. A strip cutter subdivides the cooled sheet into strings and is passed through a rope corner. The rope is coloured and shaped. The final product is formed by steam cooking the coloured and shaped material.

Fish sausage

Fish sausages are surimi or fish mince mixed with additives, stuffed in suitable casings and heat processed. The surimi or fish mince is mixed with salt (3-4%), sugar (2-3%), sodium glutamate (0.3%) starch and soy protein in a silent cutter and stuffed in casings by an automatic screw stuffer. The stuffed sausage is heated in hot water at 85-90°C for 40-60 min. After heating, it is cooled slowly to avoid shrinking of the tube and then stored at refrigerated temperature. The production of fish sausage in India is rather insignificant, although market potential for this product is good. Sausages prepared from rohu mince treated with potassium sorbate had a shelf life of 16 days at refrigerated temperatures.

Emerging technologies for value addition of fish

Retort pouch processing:

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

Extrusion:

In order to improve the utilization of underutilized fisheries resources, there is a need to minimize the post-harvest losses, develop innovative processing technologies and utilize processing waste for industrial and human use. One such technology, which will be suitable for utilization of low value fish or by catch, is extrusion technology. Use of fish mince with cereals for extrusion process will enable production of shelf-stable products at ambient temperature. Extrusion cooking is used in the manufacture of food products such as ready-to-eat breakfast cereals, expanded snacks, pasta, fat-bread, soup and drink bases. The raw material in the form of powder at ambient temperature is fed into extruder at a known feeding rate. The material first gets compacted and then softens and gelatinizes and/or melts to form a plasticized material, which flows downstream into extruder channel. Basically, an extruder is a pump, heat exchanger and bio-reactor that simultaneously transfer, mixes, heats, shears, stretches, shapes and transforms chemically and physically at elevated pressure and temperature in a short time. At times, the extrusion cooking process is also referred as High Temperature Short Time process. In extrusion process gelatinization of starch and denaturation of protein ingredient is achieved by combined effect of temperature and mechanical shear. The conversion of raw starch to cook and digestible materials by the application of heat and moisture is called gelatinization. During extrusion the conditions that prevail are high temperature, high shear rate and low moisture available for starch may lead to breakdown of starch molecules to dextrins.

Irradiation

Irradiation is a physical treatment that consists of exposing foods to the direct action of electronic, electromagnetic rays to assure the innocuity of foods and to prolong the shelf life. Irradiation of food can control insect infestation, reduce the numbers of pathogenic or spoilage microorganisms, and delay or eliminate natural biological processes such as ripening, germination, or sprouting in fresh food. Like all preservation methods, irradiation should supplement rather than replace good food hygiene, handling, and preparation practices.

Three types of ionizing radiation are used in commercial radiation to process products such as foods and medical and pharmaceutical devices (International Atomic Energy Agency (IAEA), radiation from high-energy gamma rays, X-rays, and accelerated electrons.

- Gamma rays, which are produced by radioactive substances (called radioisotopes). The approved sources of gamma rays for food irradiation are the radionuclides cobalt-60 (^{60}Co; the most common) and cesium-137 (^{137}Cs). They contain energy levels of 1.17 and 1.33 MeV (^{60}Co) and 0.662 MeV (^{137}Cs).
- Electron beams, which are produced in accelerators, such as in a linear accelerator (linac) or a Van de Graaff generator at nearly the speed of light. Maximum quantum energy is not to exceed 10 MeV.
- X-rays or decelerating rays, which can be likewise produced in accelerators. Maximum quantum energy of the electrons is not to exceed 5 MeV

Different forms of irradiation treatment are raduarization (for shelf-life extension), radicidation (for elimination of target pathogens) and radappertization (for sterilization). Radiation processing is widely used for medical product sterilization and food irradiation. Moreover, the use of irradiation has become a standard treatment to sterilize packages in aseptic processing of foods and pharmaceuticals. Irradiation produces some chemical changes, which, although lethal to foodborne bacteria, do not affect the nutritional quality of the food but lead to the production of small amounts of radiolytic products. Gamma irradiation has been considered as an interesting method of preservation to extend the shelf life of fish and also to reduce qualitatively and quantitatively the microbial population in fish and fish products. Irradiation doses of 2–7 kGy can reduce important food pathogens such as Salmonella, Listeria, and Vibrio spp., as well as many fish-specific spoilers such as *Pseudomonaceae* and *Enterobacteriaceae* that can be significantly decreased in number.

Microwave processing:

The applications of microwave heating on fish processing include drying, pasteurization, sterilization, thawing, tempering, baking etc. Microwaves are electromagnetic waves whose frequency varies within 300 MHz to 300 GHz. Microwave heating is caused by the ability of the materials to absorb microwave energy and convert it into heat. Microwave heating of food materials mainly occurs due to dipolar and ionic mechanisms. Water content in the food material causes dielectric heating due to the dipolar nature of water. When an oscillating electric field is incident on the water molecules, the permanently polarized dipolar molecules try to realign in the direction of the electric field. At high frequency electric field, this realignment occurs at a million times per second and causes internal friction of molecules resulting in the volumetric heating of the material. Microwave heating also occur due to the oscillatory migration of ions in the food which generates heat in the presence of a high frequency oscillating electric field. Studies showed that chemical changes involved during different microwave cooking practices of skipjack tuna and will retain omega-3 fatty acids compared to frying/canning. Microwave blanching can be carried out for color retention and enzyme inactivation which is carried out by immersing food materials in hot water, steam or boiling solutions containing acids or salts. Microwave drying is used to remove moisture from fish and fishery products. Microwave drying has advantage of fast drying rates and improving the quality of product. In microwave drying, due to volumetric heating, the vapors are generated inside and an internal pressure gradient is developed which forces the water outside. Thus, shrinkage of food materials is prevented in microwave drying. One of the disadvantages of microwave drying is that excessive temperature along the corner or edges of food products results in scorching and production of off-flavors especially during final stages of drying. Microwave combined with other drying methods such as air drying or infrared or vacuum drying or freeze drying gave better drying characteristics compared to their respective drying methods or microwave drying alone.

Ohmic heating:

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

Accelerated Freeze Drying

Accelerated freeze-drying is now being increasingly used for the preservation of high value food products. The product has the advantages like absence of shrinkage, quick re-hydration upto 95%, minimum heat induced damage etc. In India this technique is now applied for processing shrimp, squid rings etc. The possibilities for various ready-to-eat products based on fish and shellfish employing this technique are immense. In this, there is a speeding of the freeze-drying process, as a result of modification in the heating mechanism. Food is arranged in single layers between metal sheets or grids held in a tray. This is kept between the heating plates. When the required pressure and temperature is attained in the chamber, fluid contained within the hollow plates is heated to temperature of 60 to 100° C. The heat is conducted through the metal mesh, and trays to the product while allowing the water vapour to escape through the mesh channels to the side of the heating plates from where it is removed. Otherwise, the pressure at the food surface would increase and the ice will melt. When the ice is melted from the surface the pressure is applied to the plates using a hydraulic mechanism so that the mesh will be pressed against the surface of the fish giving more direct heat contact to the product. At the same time the temperature of the heating material is reduced since, after sublimation the surface temperature of the fish will be the same as that of heating plates (Balachandran, 2001). This method appeared to reduce the freeze-drying time appreciably from 10-12 hours to 6-7 hours, depending on the thickness of the food, temperature and pressure, and hence it is termed as accelerated freeze drying.

Infrared and Radiofrequency Processing Technologies:

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

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

High pressure processing:

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

Ultrasound Processing:

Ultrasound refers to sound that is just above the range of human hearing, i.e., above frequency of 20 kHz. Ultrasound when propagated through a biological structure induces compressions and depressions of the medium particles imparting a high amount of energy to the material. The sound ranges for food applications employed can be divided into two, namely, low energy, high frequency diagnostic ultrasound and high energy low frequency power ultrasound. Low energy applications involve the use of ultrasound in the frequency range of 5-10 MHz at intensities below 1 W/cm^2. Ultrasonic waves at this range are capable of causing physical, mechanical, or chemical changes in the material leading to disrupting the physical integrity, acceleration of certain chemical reactions through generation of immense pressure, shear, and temperature gradient in the medium. Ultrasonics has been successfully used to inactivate *Salmonella* spp., *Escherichia coli*, *Listeria monocytogenes*, *Staphylcoccus aureus* and other pathogens.

Bio preservation:

Bacteriocins are a heterogeneous group of antibacterial proteins that vary in spectrum of activity, mode of action, molecular weight, genetic origin and biochemical properties. Various spices and essential oils have preservative properties and have been used to extend the storage life of fish and fishery products. Natural compounds such as essential oils, chitosan, nisin and lysozyme, bacteriocins have been investigated to replace chemical preservatives and to obtain green label products.

Application of enzymes:

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

Innovative packaging Technologies

Vacuum packaging:

Vacuum packaging involves the removal of air from the package and the application of a hermetic seal. The air removal creates a vacuum inside the packs and lack of O_2 in packages may minimize the oxidative deteriorative reactions and aerobic bacterial growth. Vacuum packaging can considerably extend the viable shelf life of many cooked foods. The use of vacuum packaging, in gas impermeable and heat stable materials, has many advantages, which include; no or low risks of post pasteurization contamination, ease of handling, Inhibition of growth of aerobic spoilage organisms and inhibition or slowing of deleterious oxidative reactions in the food during storage due to oxygen barrier properties of the packaging material. There are number of criteria required for the films used for vacuum packaging in large scale production methods. These requirements include: high durability, i.e. ability to withstand considerable mechanical stresses during packaging, handling and transport, retention of flexibility even at low temperatures (-2 to 4°C) to enable satisfactory handling in the packaging and refrigeration rooms, ability to withstand heating to at least 150°C without structural damage, leaching of potentially toxic plastics or plasticizers, impermeability to liquids, including oils and fats and macromolecules, impermeability to gases, in particular oxygen, so that oxidative deterioration of the packaged food stuffs is limited or inhibited, manufactured from non-toxic, food acceptable, odorless materials and must be able to create airtight durable heat seals to close packs. Many of these criteria have been met by a range of materials mostly multilaminated plastics. Vacuum packed foods maintain their freshness and flavor 3-5 times longer than with conventional storage methods, because they don't come in contact with oxygen. Foods maintain their texture and appearance, because microorganisms such as bacteria mold and yeast cannot grow in a vacuum. Freezer burn is eliminated, because foods no longer become dehydrated from contact with cold, dry air. Moist foods won't dry out, because there's no air to absorb the moisture from the food. Dry, solid foods, won't become hard, because they don't come in contact with air and, therefore, can't absorb moisture from the air. Foods that are high in fats and oils won't become rancid, because there's no oxygen coming in contact with the fats, which causes the rancid taste and smell.

Vacuum packaging machine and Vacuum-packed fish

Modified Atmospheric packaging:

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

Inhibition by Carbon dioxide manifests in an increased lag phase and a slower rate of growth of microorganisms during logorathmic phase. Inhibition by Carbon dioxide was found to be more effective when the product was stored at the lowest range of refrigerated temperatures. Packaging materials generally employed for this purpose are flexible films of nylon/surylyn laminates, PVC moulded trays laminated with polythene, polyester/low density polythene film etc. The use of high barrier film along with MAP that contains CO_2 effectively inhibits bacterial growth during refrigerated storage of packaged fresh fishery products.

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

Modified Atmosphere packaging equipment and Gas composition analyzer

Active Packaging

Active packaging refers to the incorporation of certain additives into packaging systems to alter the packaging atmosphere and to maintain it throughout the storage period with the aim of maintaining or extending product quality and shelf-life. There are two types of active packaging systems viz., scavenging systems (O_2, CO_2, H_2O, ethylene, taints) and releasing systems (CO_2, H_2O, antimicrobials, antioxidants**).** Studies conducted at CIFT on the active packaging of fishery products have demonstrated a significant extension of shelf life over air packed samples (Mohan *et al.*, 2008; 2009a; 2009b; 2010)

Intelligent Packaging

Intelligent packaging systems monitor the condition of packaged foods and communicate information about quality of the packed food during transportation and storage (Brody *et al.,* 2001; Kerry *et al.*, 2006). This consists of an external or internal indicator which can indicate whether the quality of the packed food has decreased before the product has deteriorated. Examples are Time Temperature Indicators (TTI) and Freshness Indicators. Time Temperature Indicator is simple devices which can show an easily measurable, time-temperature dependent change that reflect the full time temperature history of a food product. It is attached to the packaging material externally and activated by adhesion of the two materials. Freshness indicators indicate the spoilage or lack or freshness of the product, in addition to temperature abuse or package leakage. This is based on the reaction with volatile metabolites produced during ageing of foods which gives a visible colour change as an indicator. The U.S. Food and Drug Administration (FDA) recognize TTI in the 3rd edition of the Fish and Fisheries Products Hazards and Control Guidance.

Byproducts from Fish & Shellfish

Shark Fins

Fresh shark fins are dried in the sun to a moisture level of 10%. The shark fins are further processed to obtain shark a fin ray, which is used in making exotic soups. The best rays are obtained from the dorsal and ventral fins of the shark

Squalene

Squalene is an unsaturated hydrocarbon found in the unsaponifiable fraction of fish oils, especially of certain species of sharks. Liver oil containing high proportion of squalene is distilled in a stainless-steel glass lined vessel under a vacuum of 2 mm bar. Fraction distilled between 240 and 245°C is collected. All operations are to be carried out preferably in an inert atmosphere, as squalene is easily oxidisable. Squalene is widely used in pharmaceuticals and cosmetics

Shark cartilage

Shark cartilage assumes importance because of the presence of chondroitin sulphate, which is a mucopolysaccharide. Chondroitin sulphate has therapeutic uses and is effective in reducing cancer related tumors and inflammation, and pain associated with arthritis, psoriasis and enteritis. Oral intake of shark cartilage is reported to be effective in the above cases. The bones separated from the shark are cleaned for removing the adhering meat, blood stain etc. After washing well, the bones are preserved by drying at a temperature not exceeding 70°C to a moisture level below 6 %.

Fish calcium

Calcium powder processed from the backbone of tuna can be used to combat calcium deficiency in the diet of children, which otherwise can lead to bone failure and spine curvature. The method of production of calcium involves mainly removing the gelatin from the crushed bones and pulverizing the remaining portion. A process recommended for processing calcium powder from the backbone of skipjack tuna involves the following steps. The bone frame is crushed and washed in clean water a number of times. A 10 % solution of calcium carbonate is added to the residue and is left for an hour. After draining the solution washing and treatment with calcium carbonate is repeated a number of times. Finally washed bone residue is washed and dried and pulverized to the required mesh size.

Chitin and Chitosan

The body peelings from shrimp processing plants are a major and economical source of chitin. Lobster and crab shell waste also contain sizeable quantities of chitin. The shells are deproteinized with alkali and demineralized with dilute hydrochloric acid. The fibrous portion obtained, after washing is chitin. Chitin can be deacetylated with caustic soda to give chitosan. The deacetylation is achieved by treatment of chitin with (40% W/W) aqueous potassium or sodium hydroxide at about 100°C. The product obtained is dried in hot air dryer to a temperature not exceeding 60°C. Chitosan finds extensive applications in many industries such as pharmaceutical, textiles, paper, water purification etc.

Fish maws/Isinglass

Air bladders of hake, sturgeon and carp are the main sources of isinglass. In India it is obtained from eel, catfish, carp, catla etc. The dried bladders are softened by soaking in water for several hours. They are mechanically cut into small pieces and pressed between hollow iron rollers, then converting them into thin strips of 3-6 mm thickness and then dried. It is used mainly for clarifying beverages, as an adhesive base in confectionery products, glass, pottery and leather and also as an edible luxury. Its exports are mainly confined, at present, to Hong Kong, Singapore and Germany.

Livestock feed from cephalopod processing waste

A simple environmentally friendly process has been developed by CIFT to convert the squid and cuttlefish waste to livestock feed. The basic principle is lowering the pH by addition of formic acid and liquefying by the action of proteolytic enzymes already present in the fish. The liquefaction will be over by 3-4 days, resulting in a product with a pleasant odour. The silage formed in the liquid state is then converted into solid form by mixing with de-oiled rice bran or wheat bran and sun drying to moisture content below 10%, thereby easing the storage and transportation problems. The product after mixing with rice bran and drying contains 24-26% protein along with calcium, phosphorous and vitamins etc. The product has very good shelf life because of its very low-fat content.

Conclusion

Value can be added to fish and fishery products according to the requirements of different markets. These products range from live fish and shellfish to ready to serve convenience products. In general, value-added food products are raw or pre-processed commodities whose value has been increased through the addition of ingredients or processes that make them more attractive to the buyer and/or more readily usable by the consumer. It is a production/marketing strategy driven by customer needs and perceptions. Technology developments in fish processing offer scope for innovation, increase in productivity, increase in shelf life, improve food safety and reduce waste during processing operations. A large number of value added and diversified products both for export and internal market based on fish, shrimp, lobster, squid, cuttlefish, bivalves etc. have been identified.

14. Seafood hadling and low temperature preservation

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The significance of fish as a powerful source of nutrients is well known. It's loaded with important components such as proteins, omega-3 fatty acids, vitamins and minerals which are incredibly important for the function of body. However, seafood is simultaneously highly perishable and hence requires effective preservation protocols to maintain its quality and safety. Ensuring the quality of fish begins with harvest and extends throughout the post-harvest chain. Fish being highly delicate, critically requires efficient cold chain management throughout the supply chain to guarantee quality of the fresh, chilled, frozen or processed fishery products. Along the cold chain, right from the harvesting routed through onboard storage, landing centre, transportation, till domestic/export/retail marketing, the qualitative loss account for 2 -5 % while quantitative loss ranges from 3 - 17 %, being maximum during harvesting. Therefore, strengthening of the harvest practices by proper measures as well as post- harvest infrastructure facilities such as cold storage facilities, ice plants, freezing/processing units, roads and transportation, modern and hygienic wholesale and retail market outlets etc., as well as effective marketing system in identified areas are the key requirements for the development of this sector. There are, however, several constraints in handling the fish; the important among them are the bacteriological, chemical and physical processes that cause degradation of fish. Proper handling and preservation can increase its shelf life and retain its quality and nutritional attributes. The objective of handling, processing and preservation is to control or reduce the spoilage process so that the final product is wholesome and safe for the consumer. Fish and fishery products brought to market in a well-preserved condition will generally command higher prices, both at wholesale and retail levels, and thus give better returns to the fishing operation.

Effective handling and transportation can help to deliver the fish in the same condition as it is at the time of catch within the limits of practicability under good commercial practice. For this, the general and important rules to be followed include: Maintaining the fish at low temperature throughout the post harvest chain by proper icing; Avoid mishandling of the fish; Sorting of fish, catch wise (species-wise, size-wise); Use of clean containers/surface for the holding/transportation of fish; Use of good quality water and ice; Personnel hygiene at every handling stage.

HYGIENIC ONBOARD FISH HANDLING

Handling of fish starts the moment they are harvested and refers to the conditions that fish are subjected to, after harvest till conveyed on-shore. Careful and hygienic handling of fish onboard the fishing vessel can ensure enhanced longevity of fish. These mainly include proper vessel design and maintenance, cleanliness of vessel premises, workers hygiene and

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maintenance of cold chain. For this:

1. Vessels must be designed and constructed so as to protect fish from contamination by bilge-water, sewage, smoke, fuel or other objectionable substances.
2. Equipment, materials, surfaces and surface coatings that come into contact with fish and fishery products must be corrosion-proof, durable, non-toxic as well as easy to clean and disinfect.
3. Fishing vessels should be designed and equipped with suitable holds, tanks or containers to preserve fresh fish and fishery products throughout the fishing period.
4. Chilling devices must allow easy monitoring of temperatures.
5. Ensuring availability of potable water for washing and cleaning of fish and fishery products retained on board as well as for ice that is used to chill the samples.
6. All vessels must be kept free of pests using pest control devices.
7. Sorting and heading and/or gutting of fish must be carried out hygienically as soon as practicable after capture and the eviscerated products must be washed immediately and thoroughly with either potable water or clean seawater.
8. Crew members must maintain a reasonable standard of hygiene and prevent contamination of fish or fishery products and where appropriate, wear suitable protective clothing, head covering and footwear.

HYGIENIC FISH HANDLING IN HARBOUR/MARKET

In the seafood supply chain, the first trade/sale point is the landing centres or harbours. These primary markets are the most crucial location which ensures the economic returns of fishermen as well as the availability of quality fish along the entire value chain. These domestic markets plays a very crucial role in the development of fisheries sector in the country as about 85% of the total fish landing is distributed through domestic markets. They play a major role in strengthening the nutritional and food security. Ensuring hygienic handling practices in domestic market helps to minimize post-harvest losses and leads to food safety. Following minimum basic requirements can ensure good hygiene in domestic market:

- Cleanliness of the market premises
- Availability of potable water, ice facility and cold storage facilities
- Hygienic stalls with proper roofing and flooring and portable display unit with facility for cutting and storage of fish
- Maintenance of proper hygiene by workers
- Proper drainage and waste management system
- Transportation facilities that ensure maintenance of cold chain
- Communication facilities
- Restroom and toilet facilities

HYGIENIC FISH HANDLING IN PROCESSING UNITS

Seafood Processing units are powerful economic drivers that has a major role in determining the domestic as well as international trade of aquatic produce. They mainly focus on value addition approaches of the fish thus improving the market value of the products. Following hygienic practices in these units will ensure improved fish quality which in turn is critical to increase marketing opportunities.

- Appropriate design and layout comprising sufficient working space under adequate hygienic conditions, an area for machinery, equipment and storage, separation of operations preventing cross-contamination, adequate natural or artificial lighting, ventilation and protection against pests.
- All food contact surfaces shall be smooth, durable, non-absorbent type, easy to maintain and clean and non-toxic.
- Availability of uninterrupted supply of portable water throughout for all processing operations.
- Availability of suitable facilities for temperature, humidity and other controls.
- All pre-processing and processing activities should be scheduled under HACCP system with proper documentation.
- Regular monitoring of processing unit for plant sanitation with an in-house laboratory and an in-process product quality check.
- Effective maintenance and sanitation systems including cleaning and sanitation procedures, pest control systems, waste management and monitoring effectiveness.
- All fish handlers should follow the recommended hygienic handling practices such as periodic medical examinations, regular cleaning and disinfection procedures prior and post to processing activities.

Strictly following these simple but important hygienic practices can definitely ensure high quality and safe fish to the consumers.

LOW TEMPERATURE PRESERVATION

Proper preservation of fish assumes greater importance so that this nutritious source is delivered in prime quality to the seafood consumers. 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 prolong 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 range 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 seafood.

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 aswell 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 cause minimum damage to the flesh.

Shelf life of iced fish

Shelf life of food is defined as the maximum length of time a given product is fit for human consumption. It 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 to eat. Shelf life of chill stored fish range from 4 to 20 days. 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 in ice storage:

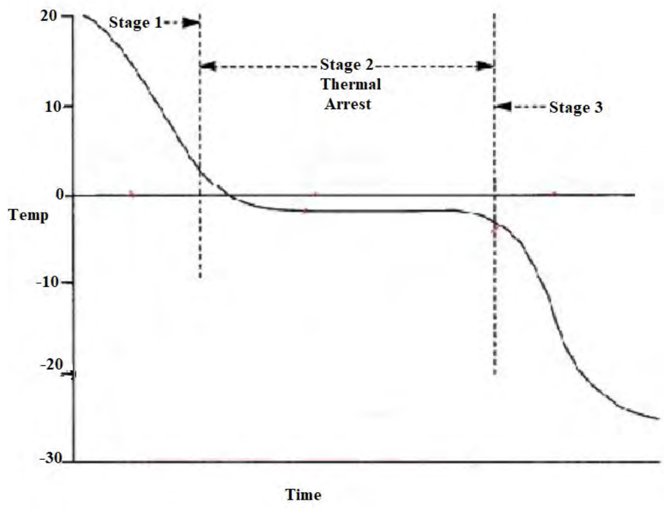
- Non-fatty fishes can be kept longer than fatty fishes
- White fleshed fishes can be kept longer than dark fleshed fishes
- Freshwater fishes can be kept longer than marine fishes
- Tropical fishes can be kept longer than temperate fishes
- Smaller species can be kept longer than big fishes
- Flat fishes can be kept longer than round fishes
- Thick skinned fishes can be kept longer than thin skinned fishes

Quality Changes in fish during the chilling/icing

- *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 2^{o}C, 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 ttechniques 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 during 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 refrigerants, 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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15. Thermal processing of fish

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Processing and preservation of food is an important activity to ensure safe food supply apart from reducing food loss. Fish being highly perishable food commodity, processing and preservation assumes great importance. There are number of reasons for processing fish and shellfish which are given below.

1. To supply safe food
2. To minimize loss/waste of valuable food commodity
3. To meet consumer preference and specified quality standards
4. To extend the shelf life of food for longer duration
5. To make profit by adding value and increasing convenience to the consumer

Thermal sterilization of foods is the most significant part of food processing industry and is one of the most effective means of preserving food supply. 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. The concept of thermal processing has come a long way since the invention of the process by French confectioner, Nicholas Appert. Later on Bigelow and Ball developed the scientific basis for calculating the sterilization process for producing safe foods. Today, thermal processing forms one of the most widely used method of preserving and extending shelf life of food products including seafood's. Thermal processing involves application of high temperature treatment for sufficient time to destroy all the microorganisms of public health and spoilage concerns. Normally, thermal processing is not designed to destroy all microorganisms in a packaged product, which may result in low quality product which destroys important nutrients. Instead of this, the pathogenic microorganisms in a hermetically sealed container are destroyed by heating and a suitable environment is created inside the container which does not support the growth of spoilage type microorganisms. Several factors must be considered for deciding the extent of heat processing which include,

a) type and heat resistance of the target microorganism, spore, or enzyme present in the food
b) pH of the food
c) heating conditions
d) thermo-physical properties of the food and the container shape and size
e) storage conditions

Thermal processing is designed to destroy different microorganisms and enzymes present in

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the food. Normally in thermal processing, exhausting step is carried out to before sealing the containers. In some cases, food is vacuum packed in hermetically sealed containers. In such cases very low levels of oxygen is intentionally achieved. Hence, the prevailing conditions are not favorable for the growth of microorganisms that require oxygen (obligate aerobes) to create food spoilage or public-health problems. Further, the spores of obligate aerobes are less heat resistant than the microbial spores that grow under anaerobic conditions (facultative or obligate anaerobes). The growth and activity of these anaerobic microorganisms are largely pH dependent. From a thermal-processing standpoint, foods are divided into three distinct pH groups which are given below. Changes in the intrinsic properties of food, mainly salt, water activity and pH are known to affect the ability of microorganisms to survive thermal processes in addition to their genotype. Due to health related concerns on the use of salt, there is increased demand to reduce salt levels in foods. The United States Food and Drug Administration (FDA) have classified foods in the federal register (21 CFR Part 114) as follows (Table 2):

1. high-acid foods (pH < 3.7; e.g., apple, apple juice, apple cider, apple sauce, berries, cherry (red sour), cranberry juice, cranberry sauce, fruit jellies, grapefruit juice, grapefruit pulp, lemon juice, lime juice, orange juice, pineapple juice, sour pickles, vinegar)
2. acid or medium-acid foods (pH 3.7 - 4.5; e.g., fruit jams, frit cocktail, grapes, tomato, tomato juice, peaches, piento, pineapple slices, potato salad, prune juice, vegetable juice)
3. low-acid foods (pH > 4.5; e.g., all meats, fish and shellfishes, vegetables, mixed entries, and most soups).

Table 2. Approximate pH range of different food

Food	pH	Food	pH
Lemon juice	2.0 - 2.6	Sweet potato	5.3 – 5.6
Apples	3.1 - 4.0	Onion	5.3 – 5.8
Blueberries	3.1 – 3.3	Spinach	5.5 – 6.8
Sauerkraut	3.3 – 3.6	Beans	5.6 – 6.5
Orange juice	3.3 – 4.2	Soybeans	6.0 – 6.6
Apricot	3.3 – 4.0	Mushroom	6.0 – 6.7
Bananas	4.5 – 5.2	Clams	6.0 – 7.1
Beef	5.1 – 7.0	Salmon	6.1 – 6.3
Carrot	4.9 – 5.2	Coconut milk	6.1 – 7.0
Green pepper	5.2 – 5.9	Milk	6.4 – 6.8
Papaya	5.2 – 6.0	Chicken	6.5 – 6.7
Tuna	5.2 – 6.1	Whole egg	7.1 – 7.9

The acidity of the substrate or medium in which micro-organisms are present is an important factor in determining the extent of heat treatment required. With reference to thermal processing of food products, special attention should be devoted to *Clostridium botulinum* which is a highly heat resistant mesophilic gram positive, rod shaped spore-forming anaerobic pathogen that produces the toxin *botulin*. It has been generally accepted that *C. botulinum* and other spore forming, human pathogens does not grow and produce toxins below a pH of 4.6. The organisms that can grow in such acid conditions are destroyed by relatively mild heat treatments. For food with pH values greater than 4.5, which are known as low-acid products which includes fishery products, it is necessary to apply a time–temperature regime sufficient to inactivate spores of *C. botulinum* which is commonly referred to as a *botulinum cook* in the industry. 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, and this thermal process lethality time is termed the F_0 value. Although there are other microorganisms, for example *Bacillus stearothermophilus*, *B. thermoacidurans*,and *C. thermosaccolyaticum*, which are *thermophilic* in nature (optimal growth temperature ~ 50–55°C) and are more heat resistant than *C. botulinum* *a* compromise on the practical impossibility of achieving full sterility in the contents of a hermetically sealed container during commercial heat processing, whereby the initial bacterial load is destroyed through sufficient decimal reductions to reduce the possibility of a single organism surviving to an acceptably low level. This level depends on the organism, usually *Clostridium botulinum*, which the process is designed to destroy. The time required to reduce the number of spores of this organism (or any other micro-organism) by a factor of 10 at a specific reference temperature (121.1°C) is the decimal reduction time, or *D* value, denoted D_0. The D_0 value for *Clostridium botulinum* spores can be taken as 0.25 minutes. To achieve a reduction by a factor of 10^{12}, regarded as an acceptably low level, requires 3 minutes at 121.1°C, and is known as the process value, or *F* value, designated F_0 so, in this case, $F_0 = 3$, which is known as a botulinum cook which is the basis of commercial sterility.

Thermal resistance of microorganisms

For establishing a safe thermal processing, knowledge on the target microorganism or enzyme, its thermal resistance, microbiological history of the product, composition of the product and storage conditions are essential. After identifying the target microorganism, thermal resistance of the microorganism must be determined under conditions similar to the container. Thermal destruction of microorganism generally follow a first-order reaction indicating a logarithmic order of death i.e., the logarithm of the number of microorganisms surviving a given heat treatment at a particular temperature plotted against heating time (survivor curve) will give a straight line (Figure 1). The microbial destruction rate is generally defined in terms of a decimal reduction time (D value) which represents a heating time that results in 90% destruction of the existing microbial population or one decimal reduction in the surviving microbial population. Graphically, this represents the time between which the survival curve passes through one logarithmic cycle (Fig. 1). Mathematically,

$$D = (t_2 - t_1) / (\log a - \log b)$$

where, *a* and *b* are the survivor counts following heating for t_1 and t_2 min, respectively. As the survivor or destruction curve follows the logarithmic nature, the complete destruction of the microorganisms is theoretically not possible.

From the survivor curve, as the graph is known, it can be seen that the time interval required to bring about one decimal reduction, i.e. 90% reduction in the number of survivors is constant.

This means that the time to reduce the spore population from 10,000 to 1000 is the same as the time required to reduce the spore population from 1000 to 100. This time interval is known as the decimal reduction time or the 'D' value. 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, faster the rate of thermal destruction and lower the D value. The unit of measurement for D is 'minute'. An important feature of the survivor curve is that no matter how many decimal reductions in spore numbers are brought about by a thermal process, there will always be some probability of spore survival. Different micro-organisms and their spores have different D values as shown in Table–3.

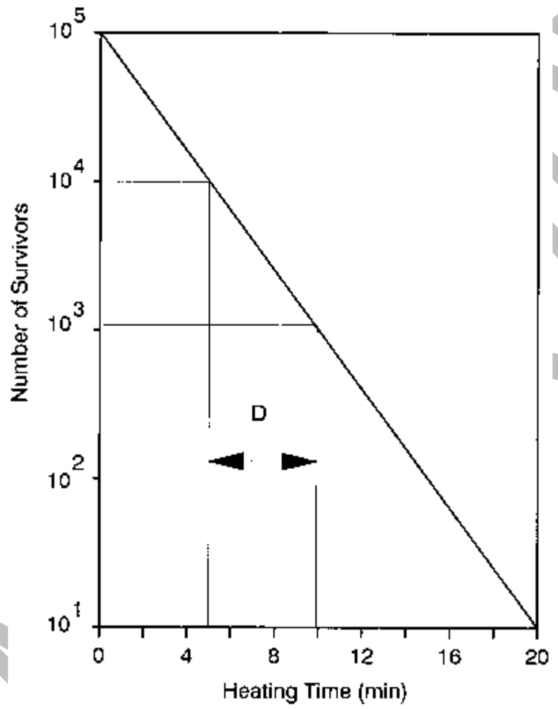

Fig 1. Survivor curve

Table-3. D value (at 121.1°C) of some bacterial spores

Microorganism	Optimum growth temperature (°C)	D value (min)
Bacillus stearothermophilus	55	4 to 5
Clostridium thermosaccharolyticum	55	3 to 4
Clostridium nigrificans	55	2 to 3
Clostridium botulinum types A & B	37	0.1 to 0.25
Clostridium sporogenes (PA 3679)	37	0.1 to 1.5

Bacillus coagulans	37	0.01 to 0.07
Non-spore forming mesophilic bacterial yeasts and moulds	30 - 35	0.5 to 1.0

The thermal death time may be defined as the time required at any specified temperature to inactivate an arbitrarily chosen proportion of the spores, the higher the proportion the greater will be the margin of safety. TDT is the heating time required to cause complete destruction of a microbial population. Such data are obtained by subjecting a microbial population to a series of heat treatments at a given temperature and testing for survivors. The thermal death time curve is obtained by plotting the thermal death time on logarithmic scale against temperature of heating on linear scale on a semilogarithmic graph paper (Fig. 2). Comparing TDT approach with the decimal reduction approach, one can easily recognize that the TDT value depends on the initial microbial load (while D value does not). Further, if 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. 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 temperature sensitivity indicator is defined as z, a value which represents a temperature range which results in a ten-fold change in D values or, on a semilog graph, it represents the temperature range between which the D value curve passes through one logarithmic cycle. The 'z' value which is also known as the temperature sensitivity indicator is usually taken as 10°C in the case of *C.botulinum.*

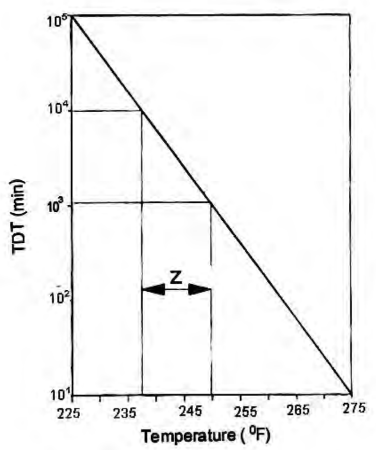

Fig. 2 TDT Curve

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. So, instead of temperatures, the corresponding lethal rates are plotted against time, the area enclosed by the graph and the ordinate represent the F value for the process. i.e.,

$$L = \frac{1}{TDT}, \quad \text{and}$$

$$F = \int_0^t L \, dt$$

Thermal Process Severity or F_0 value

From D value and the initial number of spores inside the sealed container (N_o), an idea of the severity of heat process required to reduce the spore population to a predetermined level, N_t, can be calculated from the equation:

$t = D (\log No - \log N_t)$ or $t = D \log (No/N_t)$

where, t = time required to achieve commercial sterility

This log No/N_t is sometimes referred to as the 'order of process', factor 'm' and the value of the product of m and D is called the 'process value' or 'F value'. That is:

$$F_0 = mD_{121.1°C}$$

For example, considering the generally accepted minimum process for prevention of botulism through under processing of canned fishery products preserved by heat alone, assuming that the initial loads are of the order of 1 spore/g and in line with good manufacturing practice guidelines, the final loads shall be no more than $\log 10^{-12}$ spores/g. That is 12 decimal reductions are required. It is also known as 12 D process. The minimum time required to achieve commercial sterility can be calculated from

$$t = 0.25 (\log 1 - \log 10^{-12}),$$

$$\text{i.e., } t = 0.25 \times 12 = 3.00 \text{ min}$$

Thus an F_0 value of 3.00 minutes at 121.1°C at the slowest heating point (SHP) of the container is sufficient for providing safety from pathogenic organism *C. botulinum*.

Commercial sterility

If the thermal process is sufficient to fulfill the criteria of safety and prevention of non-pathogenic spoilage under normal conditions of transport and storage, the product is said to be 'commercially sterile'. In relation to canned foods, the FAO/WHO Codex Alimentarius Commission (1983) defines, commercial sterility as 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. Apart from this concept there are circumstances where a canner will select a process which is more severe than that required for commercial sterility as in the case of mackerel and sardine where bone softening is considered desirable.

Mechanism of heat transfer

Understanding the mechanism of heat transfer is very important for thermal processing. Normally, there are three different modes of heat transfer: conduction, convection and radiation. Conduction is the transfer of heat by molecular motion in solid bodies. Convection is the transfer of heat by fluid flow, created by density differences and buoyancy effects, in fluid products. Radiation is the transfer of electromagnetic energy between two bodies at different temperatures. In thermal processed foods, the mechanism of heat transfer is either by conduction, convection or by broken heating (combination of conduction and convection). The factors which determine the mode of heat transfer are nature or consistency of a food product, the presence of particles, and the use of thickening agents and sugars. The heating modes in the thermal processing are first by heat transfer to the container or packaging material from heating and cooling media, second through the container wall and third is into the product from container wall. Convective-heat transfer rates depend largely on the velocity of flow of the media over the container, and this is an important factor to be controlled in all processing operations. In conduction heading method, energy transfer takes place when different parts of a solid body are at different temperatures. The slowest heating point or cold point in cylindrical metal containers is at its geometric centre for food products heated by conduction method. Convection heat transfer involves the transfer of heat from one location to the other through the actual movement or flow of a fluid. The slowest heating point for convection heated products in cylindrical metal container is approximately $1/10^{th}$ up from the base of the container. Packaging material forms the most important component of thermal processed foods. It should be able to withstand the severe process conditions and should prevent recontamination of the product.

Containers for thermal processing

Containers used for thermal processing should have special properties like it should withstand high temperature and pressure. Tin cans are commonly used in the canning industry and cans are denoted by trade name. First digit represents diameter of can (in inches) and next two digits represent measurement in sixteenth of inches. Apart from OTS cans, other container used in canning are: aluminium cans, tin free steel (TFS) cans, glass containers, retort pouches and semi-rigid containers.

Glass containers

Glass is a natural solution of suitable silicates formed by heat and fusion followed by immediate cooling to prevent crystallization. It is an amorphous transparent or translucent super cooled liquid. Modern glass container is made of a mixture of oxides viz., silica (S_1O_2), lime (CaO), Soda (Na_2O), alumina (Al_2O3), magnesia (MgO) and potash in definite proportions. Colouring matter and strength improvers are added to this mixture and fused at 1350 - 1400ºC and cooled sufficiently quick to solidify into a vitreous or non-crystalline condition.

Glass jars for food packing has the advantages of very low interaction with the contents and product visibility. However, they require more careful processing and handling. Glass containers used in canning should be able to withstand heat processing at high temperature and pressure. Breakage occurring due to 'thermal shock' is of greater significance in caning than other reasons of breakage. Thermal shock is due to the difference in the temperature between the inside and the outside walls of the container giving rise to different rates of expansion in the glass wall producing an internal stress. This stress can open up microscopic cracks or 'clucks' leading to large cracks and container failure. Thermal shock will be greater if the wall thickness is high. Therefore, glass container in canning should have relatively thin and uniform walls. Similarly, the bottom and the wall should have thickness as uniform as possible. More failures occur at sharp containers and flat surface and hence these should be avoided. Chemical surface coatings are often applied to make the glass more resistant to 'bruising' and to resist thermal shock. Various types of seals are available, including venting and nonventing types, in sizes from 30 to 110 mm in diameter, and made of either tin or tin-free steel. It is essential to use the correct overpressure during retorting to prevent the lid being distorted. It is also essential to preheat the jars prior to processing to prevent shock breakage.

Metal containers
Metal cans are most widely used containers for thermal processed products. Metal containers are normally made of tin, aluminium or tin-free steel.

Tin plate cans
Tinplate is low metalloid steel plate of can making quality (CMQ) coated on both sides with tin giving a final composition of 98% steel and 2% tin. Thickness varies from0.19 to 0.3 mm depending on the size of the can. Specifications with respect to content of other elements are: Carbon (0.04 - 0.12%), manganese (0.25 - 0.6%), sulphur (0.05 % max), phosphorus (0.02 % max), silicon (0.01% max) and copper (0.08% max). Corrosive nature of tin plate depends principally on the contents of copper and phosphorous. The higher the contents of these metals, greater the corrosiveness of steel. However, higher phosphorous content imparts greater stiffness to steel plate which is advantageous in certain applications where higher pressure develops in the container, eg; beer can.

Base plate for can making is manufactured using the cold reduction (CR) process. CR plates are more advantageous over hot reduced plates because of the following characteristics.

1. Superior mechanical properties – possible to use thinner plates without loss of strength
2. More uniform gauge thickness
3. Better resistance to corrosion
4. Better appearance

Aluminium cans
Pure aluminium of 99.5 to 99.7% purity is alloyed with one or more elements like magnesium, manganese, zinc, copper etc. to obtain the desired composition. Aluminium alloyed with mangnesium is the most commonly used material. Alloyed aluminium is first given an anticorrosive treatment; usually anodising in dilute sulphuric acid. The thin layer of oxides formed provides corrosion resistance. To enhance this, the sheet is further coated with a suitable lacquer.

Advantages of aluminium cans

- Light weight, slightly more than 1/3 of the weight of a similar tinplate can
- Nonreactive to many food products
- Clear, bright and aesthetic image
- Not stained by sulphur bearing compounds

- Nontoxic, does not impart metallic taste or smell to the produce
- Easy to fabricate; easy to open
- Excellent printability
- Recyclability of the metal

However, aluminium cans are not free from some disadvantages

- Thick gauge sheet needed for strength
- Not highly resistant to corrosion, acid fruits and vegetables need protection by lacquering or other means
- Special protection needed during heat processing to avoid permanent distortion
- Aluminium has great tendency to bleach some pigmented products
- Service life is less than that of tinplate for most aqueous products

Tin free steel containers

Tin free steel (TFS) apart from aluminium, is a tested and proven alternate to tinplate in food can making. It has the same steel substitute as the tinplate. It is provided with a preventive coating of chromium, chromium oxide, chromate-phosphate etc. TFS is manufactured by electroplating cold-rolled base plate with chromium in chromic acid. This process does not leave toxin substrate such as chromates or dichromates on the steel and it can be formed or drawn in the same way as tinplate.

Advantages:

- The base chromium layer provides corrosion barrier
- The superimposed layer of chromium oxide prevents rusting and pick up of iron taste
- Provides an excellent base for lacquer adhesion
- Good chemical and thermal resistance
- Tolerance to high processing temperature and greater internal pressure
- Improved and more reliable double seam

Disadvantages:

- Low abrasion resistance; hence compulsory lacquering
- Difficulty in machine soldering
- The oxide layer needs removal even for welding
- Limitations in use for acid foods

An important problem associated with TFS can ends is scuffing of lacquer on the double seam. This may occur at the seamer or downstream at different stages of lacquering. TFS cans have been found quite suitable for canning different fish in various media. Thus it holds good scope as an important alternate to tinplate cans.

Rigid plastic containers

The rigid plastic material used for thermal processing of food should withstand the rigors of the heating and cooling process. It is also necessary to control the overpressure correctly to maintain a balance between the internal pressure developed during processing and the pressure of the heating system. The main plastic materials used for heat-processed foods are polypropylene and polyethylene tetraphthalate. These are usually fabricated with an oxygen barrier layer such as ethylvinylalcohol, polyvinylidene chloride, and polyamide. These multilayer materials are used to manufacture flexible pouches and semi-rigid containers. The rigid containers have the advantage for packing microwavable products.

Retortable pouches

Retort pouch can be defined as a container produced using 2,3 or 4-ply material that, when fully sealed, will serve as a hermetically sealed container that can be sterilized in steam at pressure and temperature similar to those used for metal containers in food canning. Retort pouch has the advantages of metal can and boil-in plastic bag. Configuration of some typical pouches are:

2 ply	12µ nylon or polyester/70µ polyolefin
3 ply	12µpolyester/9-12µ aluminium foil/70µ polyolefin
4 ply	12µ polyester/9-12µaluminium foil/12µpolyester/70µ polyolefin

3-ply pouch is most commonly used in commercial canning operations. This is a three-layer structure where a thin aluminium foil is sandwiched between two thermoplastic films. The outer polyester layer provides barrier properties as well as mechanical strength. The middle aluminium foil provides protection from gas, light and water. This also ensures adequate shelf life of the product contained within. The inner film which is generally polyproplyline, provides the best heat sealing medium.

The normal design of a pouch is a flat rectangle with rounded corners with four fin seals around 1 cm wide. A tear notch in the fin allows easy opening of the pouch. The rounded corners allow safe handling and help to avoid damage to the adjacent packs. The size of the pouch is determined by the thickness that can be tolerated at the normal fill weight. The size ranges (mm) available are:

A_1	130 x 160
A_2	130 x 200
A_3	130 x 240
B_1	150 x 160
B_2	150 x 250
B_3	150 x 240
C_1	170 x 160
C_2	170 x 200
C_3	170 x 240
D_1	250 x 320 (Catering pack)
D_2	250 x 1100
D_3	250 x 480

Advantages

- Thin cross- sectional profile – hence rapid heat transfer – 30-40% saving in processing times – no over heating of the product near the walls

- Better retention of colour, flavour and nutrients
- Shelf life equal to that of the same product in metal can
- Very little storage space for empty pouches – 15% of that for cans
- Easy to open

Disadvantages

- Pouches, seals more vulnerable to damage, can be easily damaged by any sharp material, hence necessitates individual coverage
- With an over wrap cost may go up above that of cans
- Slow rate of production, 30 pouches in place of 300-400 cans per minute
- Needs special equipment
- Higher packaging cost and low output push up the cost of production

Ideally, the container used for thermal processing should fulfill following characterisitcs:

- Should withstand the sterilisation pressure and temperature
- Should be impervious to air, moisture, dust and disease germs once the can is sealed air tight
- Internal lacquer should not impart toxicity to the contents
- Strong enough to protect the contents during transportation and handling
- Inexpensive, preferably cheap enough to discard after use
- Capable of sealing at high speed
- Pleasing and sanitary appearance

Thermal Processing of Fishery Products

The thermal processing is carried out for achieving two objectives; the first is consumer safety from botulism and the second is non-pathogenic spoilage which is deemed commercially acceptable to a certain extent. If heat processing is inadequate the possibility of spoilage due to C. *botulinum* is more and will endanger the health of the consumer. Safety from botulism is made possible by making the probability of *C. botulinum* spores surviving the heat process sufficiently remote and presents no significant health risk to the consumer. An acceptable low level in the context of this dangerously pathogenic organism means less than one in a billion (10^{-12}) chance of survival. Such a low probability of spore survival is commercially acceptable as it does not represent a significant health risk. The excellent safety record of the canning industry with respect to the incidence of botulism through under processing, confirms the validity of this judgment. An acceptable low level in the case of thermophilic non-pathogenic organisms should be arrived at judiciously considering the factors like very high D value, risk of flat sour spoilage, commercial viability and profitability etc. Since non-pathogenic organisms do not endanger the health of the consumer process adequacy is generally assessed in terms of the probability of spore survival which is judged commercially acceptable. Considering all these facts, it is generally found acceptable if thermophilic spore levels are reduced to around 10^{-2} to 10^{-3} per g. Another reason for this acceptance is that the survivors will not germinate if the storage temperature is kept below the thermophilic optimum growth temperature i.e. below 35°C.

Fishery products, being categorized as low acid foods require heat processing severity with respect to *C botulinum* and F_0 value recommended is 5-20 min. Thermal processing of fishery products include various steps. These steps include, preparations like washing, beheading, gutting, removing scales / fins, cutting into required size, blanching (hot / cold), pre-cooking, filling fish pieces into containers, filling content or medium, exhausting to remove air, sealing, loading into the retort or autoclave, sterilization, washing and storing. Various packaging materials have been used from historically starting from glass container to metal container, flexible retortable pouches and rigid plastic containers. The sterilization process in the canned product can be subdivided into three phases. First one is heating phase, in which the product temperature is increased from ambient to the required sterilization temperature by means of a heating medium (water or steam). This temperature is maintained for a defined time (phase 2 = holding phasing). In (phase 3 = cooling phase) the temperature in the container is decreased by introduction of cold water into the autoclave. In order to reach temperatures above 100°C (sterilization), the thermal treatment has to be performed under pressure in pressure cookers, also called autoclaves or retorts. Simple autoclaves are generally vertical ones with the lid on top. Through the opened lid, the goods to be sterilized are loaded into the autoclave. The cans are normally placed in metal baskets. The autoclave and lid are designed to withstand higher pressures up to 5.0 bar. These types of autoclaves are best suited for smaller operations as they do not require complicated supply lines and should be available at affordable prices. Larger autoclaves are usually horizontal and loaded through a front lid. Horizontal autoclaves can be built as single or double vessel system. The double vessel systems have the advantage that the water is heated up in the upper vessel to the sterilization temperature and released into the lower (processing) vessel, when it is loaded and hermetically closed. Using the two–vessel system, the heat treatment can begin immediately without lengthy heating up of the processing vessel and the hot water can be recycled afterwards for immediate use in the following sterilization cycle. In rotary autoclaves, the basket containing the cans rotates during sterilization which enhances the heat penetration resulting in reduced process time. This technique is useful for cans with liquid or semi-liquid content as it achieves a mixing effect of the liquid/semi-liquid goods. Water immersion retorts are also used in the industry for thermal processing which is advantageous over steam retorts due to its uniform temperature distribution as there is no possibility of forming air pockets in the retort which limits the heat transfer in steam retorts. At the final stage of the sterilization process the products must be cooled as quickly as possible by introducing cold water. The contact of cold water with steam causes the latter to condense with a rapid pressure drop in the retort. However, the overpressure built up during thermal treatment within the cans, jars or pouches remain for a certain period. During this phase, when the outside pressure is low but the pressure inside the containers is still high due to high temperatures there, the pressure difference may induce permanent deformation of the containers. Therefore, high pressure difference between the autoclave and the thermal pressure in the containers must be avoided. This is generally achieved by a blast of compressed air into the autoclave at the initial phase of the cooling. Sufficient hydrostatic pressure of the introduced cooling water can also build up counter pressure so that in specific cases, in particular where strong resistant metallic cans are used, the water pressure can be sufficient and compressed air may not be needed unlike in flexible retortable pouches. After thermal processing, the containers are washed with chlorinated potable water and stored for conditioning for 2 – 4 weeks. Conditioning helps in proper mixing of the ingredients with the fish products and helps in assessing the extent of thermal process severity. If the containers do not show any deformation, it indicates the effectiveness of the thermal processing.

The important steps in canning process are:

1. Raw material 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

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16. Development of value-added fish products

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During recent decades, several development plans have focused on the aquaculture and fisheries sectors. Convenience plays important role in fish and fishery product marketing. Clean, cut ready to cook or ready eat forms of fish is demanding more and consumers are willing to pay extra premiums on it. value-added fish products are usually perceived to be those that have added ingredients such as a coating or sauce, are prepared, trimmed or in some way provide more convenience to the user. Value is a combination of quality, service, and price. The basic benefits of value addition as far as food is concerned include the functional and emotional benefits related to quality and nutrition, convenience in preparation and high sensory appeal at a reasonable cost. The dual advantages namely, finding ways for better utilization of low-value fish species and providing protein-rich convenience foods, have been pointed out as the main outcome of value addition. Value can be added to fish and fishery products according to the requirements of different markets. A number of such diverse products have already invaded the western markets. These products range from live fish and shellfish to ready to serve convenience products. As far as fish processing industry is concerned value addition is one of the possible approaches to raise profitability since this industry is becoming highly competitive and increasingly expensive.

The changing consumer pattern has created opportunities for RTE fishery products and fortified foods with fish ingredients which require minimal preparation time. While battering and breading are the most common techniques, other processing methods include chilling, freezing, canning, frying, drying, extrusion, and fermentation. Even though landings from small-scale fisheries are scattered, small in volume, and mixed in terms of species caught, they can be prepared in innovative value-added forms for domestic and export markets. In the case of finfish, the major species of economic importance produced by the small-scale capture fisheries sector in significant volumes are skipjack tuna, yellowfin tuna, croaker, kingfish, ribbonfish, seabass and pomfret, plus a host of fishes caught by seine nets such as sardines, mackerels and anchovies. Skipjack and yellowfin have good potential for value addition. The present range of skipjack products could be further expanded to include improved smoked/dried forms such as katsuobushi and arabushi for the Japanese market, dried and smoked fish flakes, fish extracts and bouillon. With proper on-board handling, yellowfin tuna loins, steaks and sashimi could also be prepared by the smallscale sector for export. Pelagic fishes like sardines, mackerels and anchovies, caught by traditional fishermen using local gears, could be processed into different products for the local and export markets. Dressed and marinated mackerels and sardines have a potential market in the Middle East. If anchovies could be better handled on board, they could be boiled and dried, as there is a good market for the product in the coastal provinces and the Persian Gulf countries.

Being one of the fastest growing economies and the second largest consumer market in

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the world, India offers a strong platform for processed seafood industry. Fish and fish-based meals are popularizing all over the world due to health concerns. Product development can play a great role in this endeavour. The adequately skilled manpower pool and the upper-hands in several agri-commodities are added advantages to make strong market capture. The prevalent methods in global processed seafood market are segmented into salting, smoking, drying, canning, freezing, curing, dehydration, pickling and blanching, surimi processing etc. Minimal processing, souz-vide and irradiation technologies are certain high-end technologies, but limitedly adopted by the industry. Yet, most of our exports currently are in the frozen form. By doing so, we are not extracting full benefits from our aquatic resources (FAO, 2005). A value addition level of 23% is reported for seafood in India but not beyond the level of dressed fish (deveined/ blanched in the case of shrimp). The increased production of Vannamei shrimp, increased productivity of Black tiger shrimp and increased export of chilled items have helped to achieve higher exports. However, the bulk of the fishery products exported come under the category of frozen products. Value addition is the key word in the Indian context of industrial fish processing to ensure maximum returns through diversification. Hence new processes and protocols have to be developed and standardised for better utilization of fishery resources. Development of indigenous processing machinery is a felt need for cost effective value addition in fisheries sector. Value addition has opened a new field for the profitable utilization of by-catch and low value fish catches. In India even now, majority prefer fresh fish. However, there is an increasing trend in the utilization of value-added fish products as evidenced by their availability in modern super markets as well as malls which are becoming popular. Empowerment of women and formation of self-help groups also have led to the increased small-scale level production of value-added items in recent times.

Price, quality, convenience, year-round availability, variety, nutritional concerns, safety and hygiene are principal determinants of consumer demand on fish. Food habits and food consumption behaviour directly affects the consumer concerns on price and quality. World's biggest fish consumer, Japan concerns more on fresh produce and they fetch highest prices for freshest form of the fish. Raw fish is centred for their diet and in general, they used shop daily for fresh fish. On the other hand, western markets consume cooked forms and their concerns are more on quality and food safety. Weekend shopping behaviour is popular in Western destinations and places much attention on convenience. Quality standards add extra cost to the production process and quality requirements differ from market to market. i.e. European Union market based on EU directives food safety and sanitation, US market based on United States Food and Drug Administration (USFDA) requirements and Japanese market based on Food and Sanitation Law. Especially quality concern markets are willing to pay extra for the maintenance of quality standards.

value-added fishery products primarily fall under the following categories

i) Speciality products
ii) Mince or mince-based products

iii) Battered and breaded or coated products

iv) Surimi based products

v) Ready to serve fish products in retortable pouch

vi) Extruded products

vii) Intermediate moisture products (IMF)

viii) Pickled products

- **Speciality products**

The most popular products under this category includes

✓ Stretched shrimp (Nobashi)

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

✓ Sushi (Cooked butterfly shrimp)

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

✓ Skewered shrimp

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

✓ Shrimp head-on cooked (centre peeled)

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

- **Battered and breaded fish products**

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

- **Mince based products**

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

- **Surimi and surimi-based products**

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

- **Ready to serve fish products in retortable pouch**

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

- **Extruded products**

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

Opportunities in culture sector

The long coastline of the country along with large number of calm bays and lagoons offer good scope for the development of coastal farming. At present, coastal farming is largely restricted to mussel and oyster farming along the selected coastal belts. In view of the available potential that exists for brackish water aquaculture and mariculture, developmental measures are being initiated recently in large scale to make these activities significant contributors in seafood production. During the last couple of decades, brackish water aquaculture sector has witnessed overwhelming growth and is now almost synonymous with Pacific white shrimp (*L. vannamei)* culture. Captive breeding and rearing of Asian seabass (*Latescalcarifer*), pearlspot (*Etroplus suratensis*) and Nile tilapia (*Oreochromis niloticus*), Hilsa (*Tenualosa ilisha*) and captive broodstock development of grey mullet (*Mugil cephalus*), are yet another milestones in the brackish water farming. Lately, the intense research efforts from R&D Institutions have led to development of the base technology for the captive breeding and rearing of commercial finfishes including cobia, *Rachycentron canadum,* silver pompano (*Trachinotusblochii*) and orange spotted grouper (*Epinephelus coioides*), with which open sea farming has gained a huge mileage in the run towards blue economy. The results are highly encouraging for the coastal cage and pen culture trials initiated with cobia, seabass, silver pompano, groupers, red snapper, breams, Nile tilapia, lobsters and mud crab. Countries such as China, Vietnam, Thailand and Indonesia have gone far ahead in coastal farming while India is yet to make a mark. Mud crab is yet another sought after variety and fetches INR 1000 - INR 1400 per Kg in the world market. Canned crab meat, chilled pasteurised crab meat, crab cut, fresh whole cooked, frozen whole-cooked, frozen sections or clusters and frozen "snap and eat" legs are some of the crab-based products available in market. As all these resources have good export potential, the present scenario demands a promisive protocol for processing and value addition so as to identify them as money spinners in export market.

Value addition: future dimensions

Value addition is not widely attempted with farmed varieties, compared to the enormous reports available on wild varieties. The concept of value addition in seafood sector covers the range of products from live fish and shellfish to ready-to-eat/serve convenience products. Being the largest producer of several agri-commodities, there are ample opportunities for value addition and product development, especially Ready To Eat/ Ready To Cook (RTE/RTC) products for the domestic as well as export market. Ethnic recipes of Indian taste like fish/shrimp pickle, fish/shrimp dishes of different cultural populations, marinated fish with Indian spices etc. offer attractive opportunities for seafood processors. However, these attractive elements are flattened by the poor infrastructure development and capital investment which considerably retaliated the growth of processed seafood market of the country in the past years, both in domestic and export domain.

Surimi and surimi-based products are yet another least explored area of value addition in the country, inspite of having a number of lean varieties of candidate species globally identified for surimi manufacturing. Surimi, a wet concentrate of myofibrillar protein, is an intermediate product in the line of globally high demanded candidate products such as sausage, analogue products, and imitation products. Worldwide, there is a continuous search of raw material which is suitable for surimi production. Surimi production from farmed species shows promising potential for a variety of value-added products, and indirectly the better utilization of locally reared species. Furthermore, the utilisation of farmed varieties for surimi and surimi-based products will strengthen the link between increased production and resource utilization.

Thermal processing, though an investment intensive process, can fetch higher margins in export market. It is a process of great technological importance in many advanced countries. However, some species do not adapt to thermal processing as the flesh disintegrates under the severe thermal processing conditions. Thus, the consumer is accustomed to a limited variety of canned marine species such as tuna, crab, lobster and shrimp. Hence, a detailed investigation on the suitability of brackish or saline water raised emerging species for thermal processing is demanded which will further broaden the scope of value addition.

Over the years, consumer demand has been changed into more convenient on-the-go products, having superior nutritional value. In this line, a series of intermediate or low moisture foods such as nutritional bars, meat flakes, pasta, noodles etc, have invaded the supermarket shelves. The intermediate foods are foods having low water activity (0.7-0.9), which can be used with/ without rehydration and are shelf stable for longer period without refrigeration. Many farmed species such as Nile Tilapia and Asian Seabass is said to have whiter, and tastier flesh, which is best suitable for the product development. The conversion of white meat to suitable convenient ready to eat products will pave a way for value addition to these species.

Although fermentation has traditionally been used to preserve fresh fish, especially in tropical climates, today it is used to enhance nutritive value, improve appearance and taste, destroy undesirable factors, and also to reduce the energy needed for cooking. However, it takes long duration to develop the characteristic features of fermentation. Similarly, smoking of fish is done primarily for the unique taste and flavour, however the texture of flesh may be affected during the smoking process. Hence, preparation of flavoured products with typical flavour extracts may be advised to reduce the process time and can be projected as a minimal processing protocol with product diversification scope for chilled high value fishes like sea bass, cobia, pompano, and grouper. Also, this opens up value addition opportunities in terms of less intense flavour of cultured species owing to the difference in food chain followed in captive condition compared to the basic seaweed-based food pyramid in marine ecosystem.

Curing and drying, eventhough an age-old practice, opens up new dimensions and possibilities towards value addition in domestic as well as overseas markets. In India as per the estimates, about 17-20% of the total catch is converted to dried products and dry fish export contributes to about 7.86% of total fish exports. The major importing countries are Sri Lanka, Malaysia, Indonesia, Singapore and United Arab Emirates. However, there are several factors hindering the addition of dried fishery products to the product profile. The major one being, drying is still considered a traditional method of processing, and hence standard operating procedures are seldom followed. Moreover, there is a general conception that drying is a secondary method for preserving low value varieties and quality compromised materials. Attempts towards improving the handling practices right from the point of raw material harvesting till marketing, popularisation of improved packaging practices, use of hygienic energy efficient mechanical driers, and adequate extension services can facilitate better adoption of drying practice in seafood sector.

Marketing of value-added products

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

Future perspectives

The current status of captive farming in Asia, especially in cages and pens, and the developments witnessed globally suggest that the farming of high value fishes such as seabass, mullet, pearlspot, silver pompano grouper, cobia and red snapper has a bright future. They have several desirable traits, most importantly a rapid growth rate under tropical climate and good flesh quality. Similarly, many of the molluscan candidates, in particular, mussels and oysters have captured wide popularity in recent years. As the top leading countries in aquaculture, the future production from China and India is likely to be a major factor in popularisation of these species for commercial processing operations. Countries such as Vietnam, Thailand and Indonesia have gone far ahead in coastal farming, while India is yet to make a mark, eventhough we are having a vast coastal line and all the favourable climatic advantages of a tropical country. This increasingly demands viable processing, product diversification, value addition and live transportation options for channelizing the harvested resources to domestic and international markets, which is expected to make significant increase in the country's foreign currency earning. The immediate benefit expected through brackish water/saline water farming promotion is minimisation of the dependency on marine capture fisheries for raw material supply, which is already in a highly stagnated and more or less in a depleted status. A long-term benefit envisioned is to present a viable option for the minimisation of use of hazardous preservatives, as practiced nowadays for extending the holding time of raw material with vendors. In the case of capture fisheries, which relay on multiday fishing operations, the material is stored for more than a week before it reaches the landing centres. Unlike this, in culture fisheries the processor or the vendor is on a beneficial side that the harvest operations can be scheduled according to the market demand so as to get the material on-board at 'zero storage time'. This delivers them more retainable period, and in turn can refrain from the use of hazardous preservatives. ICAR-CIFT has initiated a three-year project on developing handling and processing protocols for emerging farmed fishery resources with emphasis on coastal enclosure systems. The project covers the various aspects on species specific on-farm handling protocols for brackishwater and mariculturespecies, novel value addition options andlive transportation protocols.

Undoubtedly in long run, technology up-gradation will continue to remain as the key element in value addition domain, supported by minimal processing options for maximum nutritional retention, innovative ideas of packaging, intelligent systems for quality monitoring etc. High Pressure Processing, eventhough not increasingly invaded in seafood sector currently, is expected to gain fast pace in coming years as a non-thermal mean to extend shelf life. Out of box thinking and product development addressing niche markets is an important strategy for improving farm income. Transferring such technologies with a viable business model has the potential to start new industry and generate additional income to the farmers. Inevitably, a solid effort for encouraging value addition in seafood sector emphasises the primary requirement of appropriate mechanisation for reducing drudgeries, upgradation of capacity and efficiency for cold chain system, as well as development of intelligent and smart transportation techniques for increased shelf life. Moreover, parallel developments should be reflected in Government policies and investor friendly incentives, in order to make the industry globally competitive.

Different institutional contexts of end-markets are linked to different forms of coordination and control of global value chains. Economically and socially important species and value chains are differing widely across Asia. Networks both local and regional enhance the value addition, brand creation and brand strengthening,, technology enhancements, profitability and market access. Value chains of the most economically important species and destinations are need to develop vision on; learning, investment, market access, sales, and exports. Sooth functioning of value chains need to assure the favorable policy environment as well as good governance system. There is an important need to identify and support promising value chains with assistance at key point in the supply chain based on collaborative analysis of challenges, joint definition of priorities, and expert assistance from industry-experienced people. Take a cluster approach only as the starting point for value chains, not as an end in itself. All actors or stakeholders of the value chains should concentrate on competitiveness and productivity and look for and exploit multiple ways to add value once initial success has been attained with a single deal. Ensure sustainability within the value chains are key important feature to cater for ever changing demands. An important need recognizes that some keys to success require mainly public sector intervention, others only private, and some a mixture of the two. Moreover, fisheries industry needs to seek private sector alliances at all stages of supply and value chains for better future.

Strengthening the weak financial structure, focus more on formal financial systems, reducing power imbalances in the governance structures and low political intervention in community level organizations, and resolving socio-cultural and environmental concerns are the major concerns on development of value chains in developing countries. The high levels of post-catch losses indicate that the urgent need of an introduction of coolers and improved ice distribution systems, proper harbors, landing sites and markets a would be an upgrade strategy that could stimulate value chain growth. While this could indeed lead to higher profitability at first, without retaining these profits and reinvesting them back in to their business, value chain actors will not be able to grow their business. Good governance systems, protection of remaining stocks and stock enhancements, stop illegal and unregulated fishing practices, improve welfare of the fishing communities, mitigation measures to climate change, etc. are the crying needs of the hour. This risk needs to be addressed through a systemic enforcement of environmental protection measures and a diversification strategy.

17. Packaging of fish products

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Introduction

Packaging is crucial to our modern food distribution and marketing systems. Without protective packaging, food spoilage and wastage would increase tremendously. The advent of modern packaging technologies and new methods of packaging materials made possible the era of convenience products. In the past packaging emphasized the expectations of the producers and distributors but now it has shifted towards the consumer since they are becoming more demanding and aware of different choices to choose from. A food package usually provides a number of functions in addition to protection. Fish is one of the most perishable of all foods. The best package material cannot improve the quality of the contents and so the fish must be of high quality prior to processing and packaging. Different products have different packaging requirements and it is important to choose suitable packaging material accordingly. The intended storage conditions of the product, i.e., temperature, relative humidity and expected shelf life have to be known. Multilayered plastics are very popular since properties of different films can be effectively used to pack different products. The basic function of food packaging is to protect the product from physical damage and contaminants, to delay microbial spoilage, to allow greater handling and to improve presentation.

Types of Packaging Material

Glass

Glass containers have been used for many centuries and still one of the important food packaging material. Glass has its unique place in food packaging since it is strong, rigid and chemically inert. It does not appreciably deteriorate with age and offers excellent barrier to solids, liquids and gases. It also gives excellent protection against odour and flavor and product visibility. Glass can also be moulded to variety of shapes and sizes. But it has disadvantages like fragility, photo oxidation and heavier in weight.

Cans

Most frequently used container for packing food for canning is tin plate can. Tin plate containers made their appearance in 1810. The base steel used for making cans is referred as CMQ or can making quality steel. Corrosion behavior, strength and durability of the tin plate depend upon the chemical composition of the steel base. The active elements are principally copper and phosphorous. The more of these elements present the greater the corrosiveness of steel. Cans are traditionally used for heat sterilized products and different types are standard tin plates, tin free steel and vacuum deposited aluminium on steel and aluminium cans. For food products packing they are coated inside to get desirable properties like acid resistance and sulphur resistance. But care has to be taken to avoid tainting of the lacquer.

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Polymer coated two-piece cans of 6 oz capacity (307 x 109) with a universal polymer coating can be widely used for a variety of products. The can is made of Electrochemically chromium coated steel (ECCS) plate with clear polyethylene terephtahalate (PET) coating on either side The finished plate has a thickness of 0.19mm (0.15 mm of base steel + 20 µ PET coating on either side). The cans are made out of the steel plate by draw and redraw (DRD) process. The chromium coating along with the PET coating provides the can with a smooth, greyish, glistening appearance in addition to act as a barrier between the product and the base steel. The bottom of the can is designed for better stackability so that it can be stacked vertically without risk of toppling on the shelf. This also helps to reduce the storage space requirement for the cans. These cans are found to be suitable for thermal processing of fish and fish products. These cans are having easy open ends. Metal cans are advantageous as packages because of superior strength, high speed manufacturing and easy filling and dosing. Disadvantages of metal cans are weight, difficulty in reclosing and disposal.

Paper

A very considerable portion of packaged foods is stored and distributed in packages made out of paper or paper based materials. Because of its low cost, easy availability and versatility, paper is likely to retain its predominant position in packaging industries. Paper is highly permeable to gases, vapour and moisture and loses its strength when wet. Ordinary paper is not grease and oil resistant, but can be made resistant by mechanical processes during manufacturing.

Paper board

Thicker paper is called as paper board. There is not a clear cut dividing line between the heaviest grade of paper and the lightest board. The lightest standard board is 0.19 mm thick and heavy papers are of 0.125 mm thickness. Paper boards are used for making corrugated fibre board cartons.

Polymer Packaging

Plastics offer several advantages over other packaging materials since they are light in weight, flexible and offers resistant to cracking. Plastics have the advantage that most of them possess excellent physical properties such as strength and toughness. The requirements with a particular food may not be met with in a single packaging material, as it may not possess all the desired properties. In such cases copolymers or laminates consisting of two or more layers of different polymers having different properties can also be used.

Low Density Polyethylene (LDPE)

Most commonly used as it possesses qualities such as transparency, water vapour impermeability, heat sealability, chemical inertness and low cost of production. Organic vapours, oxygen and carbon dioxide permeabilities are high and has poor grease barrier property. Resists temperature between – 40°C to 85°C. Polyethylene (polythene, PE) is the material consumed in the largest quantity by the packaging industry.

High Density Polyethylene (HDPE)

HDPE resins are produced by low-pressure process. HDPE posses a much more linear structure than LDPE and has up to 90% crystallinity, compared with LDPE which exhibits crystallinities as low as 50%. The material is stronger, thicker, less flexible and more brittle than LDPE and has lower permeability to gases and moisture. It has a higher softening temperature (121°C) and can therefore be heat sterilized. High molecular weight high density polythene (HM-HDPE) has very good mechanical strength, less creep and better environmental stress crack resistance property.

Linear Low Density Polythene (LLDPE)

Linear low density polythene is low density polythene produced by a low pressure process. Normal low density polythene has many -C_5H_{11} side chains. These are absent in LLDPE, allowing the molecules to pack closer together to give a very tough resin. It is virtually free of long chain branches but does contain numerous short side chains. Generally, the advantages of LLDPE over LDPE are improved chemical resistance, improved performance at both low and high temperatures, higher surface gloss, higher strength at a given density and a greater resistance to environmental stress cracking. LLDPE shows improved puncture resistance and tear strength. The superior properties of LLDPE have led to its use in new applications for polyethylene as well as the replacement of LDPE and HDPE in some areas.

Polypropylene (PP)

Polypropylene is produced by the polymerisation of propylene. All PP films have permeability about ¼ to ½ that of polyethylene. It is stronger, rigid and lighter than polyethylene.

Cast polypropylene (CPP)

It is an extruded, non oriented film and is characterized by good stiffness, grease and heat resistance and also has good moisture barrier. However, it is not a good gas barrier.

Oriented, Heat set Polypropylene (OPP):

Orientation can be in one direction (unbalanced) or in two directions equally (balanced). The resulting film is characterized by good low temperature durability, high stiffness and excellent moisture vapour transmission rate. One drawback of OPP is its low tensile strength.

Polystyrene

The material is manufactured from ethylene and benzene, which are cheap. The polymer is normally atactic and it is thus completely amorphous because of the bulky nature of the benzene rings prevents a close approach of the chains. The material offers reasonably good barrier to gases but is a poor barrier to water vapour. New applications of polystyrene involve coextrusion with barrier resins such as EVOH and poly vinylidene chloride copolymer to produce thermoformed, wide mouthed containers for shelf stable food products and multi layer blow moulded bottles. To overcome the brittleness of polystyrene, synthetic rubbers can be incorporated at levels generally not exceeding 14% w/w. High impact polystyrene is an excellent material for thermoforming. Co-polymerisation with other polymers like acrylonitrile butadene improves the flexibility. Since it is crystal clear and sparkling, it is used in blister packs and as a breathing film for packaging fresh produce. These materials have low heat sealability and often tend to stick to the jaws of heat sealer.

Polyester

Polyester can be produced by reacting ethylene glycol with terephthalic acid. Polyester film's outstanding properties as a food packaging material are its great tensile strength, low gas permeability, excellent chemical resistance, lightweight, elasticity and stability over a wide range of temperature (-60° to 220°C). The later property has led to the use of PET for boil in the bag products which are frozen before use and as over bags where they are able to withstand cooking temperatures without decomposing.

Although many films can be metallized, polyester is the most commonly used one. Metallization results in considerable improvement in barrier properties. A fast growing application for polyester is ovenable trays for frozen food and prepared meals. They are preferable to foil trays for these applications because of their ability to be micro wave processed without an outer board carton.

Polyamides (Nylon)

Polyamides are condensation products of diacids and diamine. The first polyamide produced was Nylon-6,6 made from adipic acid and hexamethylene diamine. Various grades of nylons are available. Nylon-6 is easy to handle and is abrasion-resistant. Nylon-11 and nylon-12 have superior barrier properties against oxygen and water and have lower heat seal temperatures. However, nylon-6,6 has a high melting point and hence, it is difficult to heat seal. Nylons are strong, tough, highly crystalline materials with high melting and softening points. High abrasion resistance and low gas permeability are other characteristic properties.

Polyvinyl Chloride (PVC)

The monomer is made by the addition of reaction between acetylene and hydrochloric acid. It must be plasticised to obtain the required flexibility and durability. Films with excellent gloss and transparency can be obtained provided that the correct stabilizer and plasticizer are used. Thin plasticized PVC film is widely used in supermarkets for the stretch wrapping of trays containing fresh red meat and produce. The relatively high water vapour transmission rate of PVC prevents condensation on the inside of the film. Oriented films are used for shrink-wrapping of produce and fresh meat. Unplasticized PVC as a rigid sheet material is thermoformed to produce a wide range of inserts from chocolate boxes to biscuit trays. Unplasticized PVC bottles have better clarity, oil resistance and barrier properties than those made from polyethylene. They have made extensive penetration into the market for a wide range of foods including fruit juices and edible oils.

Copolymers

When polythene resins are being manufactured it is possible to mix other monomers with ethylene so that these are incorporated in the polymer molecules. These inclusions alter the characteristics of the polythene. Vinyl acetate is commonly used and the resulting ethylene vinyl acetate (EVA) copolymers display better sealing than modified polythene. Butyl acetate is incorporated with similar effects.

Aluminium foil

Aluminum foil is defined as a solid sheet section rolled to a thickness less than 0.006 inches. Aluminum has excellent properties like thermal conductivity, light weight, corrosion resistance, grease and oil resistance, tastelessness, odourlessness, heat and flame resistance, opacity and non-toxicity. Aluminum foil free from defects is a perfect moisture and oxygen barrier. In all flexible packaging applications using aluminum foil where good moisture and oxygen barrier properties are important, the foil is almost always combined with heat sealing media such as polythene or polypropylene. It is the cheapest material to use for the properties obtained. Foils of thickness 8 to 40 microns are generally used in food packaging. Foil as such is soft and susceptible for creasing. Hence, foil is generally used as an inner layer.

Packaging of fresh fish

A suitable package for fresh fish should keep the fish moist and prevent dehydration, retard chemical and bacterial spoilage, provide a barrier against moisture and oxygen to reduce fat oxidation and prevent permeation of external odors. Generally baskets made of split bamboo, palmyrah leaf and similar plant materials were traditionally used for packing fresh iced fish. However, they do not possess adequate mechanical strength and get deformed under stacking. The porous surface of these containers tends to absorb water and accumulate slime, creating an ideal breeding ground for spoilage bacteria, which can contaminate the fish. Even though washing cleans the contaminated surfaces of the container it has been shown to be ineffective in reducing the bacterial load significantly. Sharp edges of bamboo also cause bruises on the skin of fish. Used tea chests provided with 2.5 cm thick foamed polystyrene slabs inside have been found extremely beneficial for transport of fish over long distances up to 60 h duration.

Modern insulated containers are made of HDPE or polypropylene with polyurethane insulation sandwiched between the inner and outer walls of the double walled containers. They are durable and in normal use have a life span of over 5 years. Materials such as aluminium, steel and fibreglass are also used in the construction of insulated containers. Insulation properties of these containers depend on the integrity of the layer of insulation. Contamination of insulation layer with water drastically reduces insulation properties of the medium. An insulated corrugated polypropylene container which is the lightest of all packages is used for iced fish transport. It lasts for 5 trips and being of collapsible design and lightweight, return of empty container is very easy. The use of fibreboard containers for the transportation of iced fish and frozen fish showed that fish could be transported in good with effective insulation.

Packaging of frozen fish

World trade in frozen fishery products has been increasing every year. Fish being highly perishable transportation and storage of frozen fishery products requires a cold chain and these fishery products are to be stored at temperatures below –18° C. Fishery products are frozen at – 40° C. However cold storage temperature where they are subsequently stored varies from -30 to –18° C. The enzymatic activities bring about deteriorative changes like rancidity in frozen fish products. Exposure to low temperatures for a long time may result in freezer burns. Hence for extending shelf life and further storage, packaging is of absolute importance. To get a quality frozen product in perfect condition the package must provide protection against dehydration, oxidation, flavour and odour loss and physical changes. Evaporation of moisture from the surface of the fish may occur resulting in freezer burns. In order to overcome these problems suitable packaging is absolutely necessary. The advantages of packaging frozen fish are, prevention of dehydration, prevention of rancidity in fatty fishes, protection against contamination and physical damages, convenience of handling the product and using a portion of the product, retention of flavour and colour attractive appearance of the product and to allow pack for thawing without leaching.

Primary wrap for block frozen products

The material used as a primary wrap for contact with the food is mainly Low-density polythene (LDPE). This can be in the shape of a bag or a film. Usually 2 kg or 5 lbs fish is packed along with 10-20 % glaze. Glazing should be optimum at the recommended level, since this will add to cost and weight during packaging and transportation. Alternately, films of high molecular weight high-density polyethylene (HM-HDPE), which is not as transparent as LDPE film are also used being more cost effective. 100 gauge LDPE is used for wrap while 200 gauge is used for bag. The corresponding values for HDPE are 60 and 120 gauge. Polythene films should be of food grade conforming to IS: 9845 specifications.

Duplex carton/ Inner carton

There are four types of cartons used for packaging of seafood products, which are top opening, end opening, end loading and tray type. In top opening carton system filling is done from the top. This is mainly for filling larger pieces of fish and cephalopods. End opening type cartons are used when the product is smaller and free flowing, like packaging of fish curry or soup. Here the carton is coated with polyethylene on both the inside and outside. The end loading system feeds the product from one end into a horizontal glued carton. End flaps are heat sealed or closed by tucks in flap. End loading is suitable for products packed in aluminium /carton trays. Tray type cartons consist of cartons systems/ polypropylene trays, which are sealed with a lid and used for production of frozen pre cooked food that will be heated and thawed in the package itself. To withstand heating, the board is coated with polypropylene.

The frozen blocks are wrapped in film and then packed in duplex cartons. A number of such blocks are packed in a master poly bag and then packed into master cartons. The carton should have details like net weight, type and size, name and address of the producer and the country of origin.

Master carton

In the case of frozen shrimps about 6 units of 2 kg each or 10 units of 2 kg each are packed into master cartons. Corrugated fiberboards are used for the packaging of frozen fish. They may be of virgin material and having three or five ply with liners. The cartons may be wax coated or supported with liner paper with higher wet strength to make it moisture resistant. The specifications for master carton vary depending upon the country or the type of pack.

Strapping and tying

Boxes are now mainly closed at the top and bottom by using cellophane tapes. They are also stapled or strapped by using polypropylene / high density/ rayon extruded straps. The straps are clipped or heat-sealed. The tensile strength must be great enough to withstand the load. For polypropylene the fluctuations in the tensile strength and elongation at break (%) at –20°C are comparatively less. Hence this material is most suitable when compared to HDPE where the tensile strength and elongation at break vary.

Packaging of Individually Quick Frozen (IQF) Products

Packaging requirements of IQF shrimps vary from those of block frozen. IQF shrimps are mainly packed for retail marketing in consumer packs ranging from 100g to 5 kg. An IQF pack has a single glaze on its surface and because of the larger surface area, they are vulnerable to several risk.

Essential characteristics required for packaging materials of IQF shrimps are

- Low water vapour transmission rate to reduce the risk of dehydration
- Low gas/oxygen permeability, thereby reducing the risk of oxidation and changes in colour, flavour and odour
- Flexibility to fix the contours of the food
- Resistance to puncture, brittleness and deterioration at low temperatures.
- Ease of filling

IQF shrimps are filled in primary containers along with code slip and weighed. Bar coding is nowadays adopted which will depict various product and inventory details through a series of bars. Bar coding is compulsory for products imported to the EEC and US markets. The product is filled into primary pack which heat sealed and further it is packed in master cartons for storage and transportation. The primary pack may be plastic film pouches (monofilm co-extruded film or laminated pouches). The unit pouches may be provided with unit/intermediate cartons or directly packed into master cartons. The unit/intermediate cartons are made of duplex or three ply corrugated fibreboard laminated with plastic film on the inside and outside to improve the functional properties as well as aesthetic value of the pack. The most functional cost effective film has been identified as 10 μ biaxially oriented polypropylene (BOPP). Some duplex cartons are also wax-coated. One major requirement of the master carton is high compression strength to bear weight without damage to the product. Compression strength of 500 kg is the minimum recommended specification, which might give reasonable safety to the product. The cartons are made of 5 or 7 ply corrugated fibreboard.

Battered and Breaded fish products

This forms an important class of value added products in convenience form. The battering and breading process increase the bulk of the product thus reducing the cost element. A number of value added marine products both for export and internal markets can be prepared from shrimp, squids, cuttle fish, certain species of fish and minced meat from low priced fishes. The changes taking place during frozen storage of the value added products are desiccation, discoloration, development of rancidity etc. Application of proper packaging prevents/retards these changes and enhances shelf life. Conventional packaging materials like flexible plastic films alone are not suitable for these products as they provide little mechanical protection to the products and as a result the products get damaged or broken during handling and transportation. Hence, thermoformed containers are commonly used for this purpose. The thermoformed trays produced from food grade materials are suitable for the packaging of value added fishery products both for internal and export markets. Trays made of materials like PVC, HIP and HDPE are unaffected by low temperature of frozen storage and provide protection to the contents against desiccation, oxidation etc. during prolonged storage.

Dry fish

Traditionally, coconut leaf baskets, palmyrah leaf baskets, jute sacks and news paper baskets have been used for packing and transportation of dried fish. These containers only help in transportation of the fish. They do not protect or preserve the fish. The dry fish packed in such containers have a very short shelf life and is usually not of good quality. These fishes are often found to be rancid or have mould growth. Since the packaging is permeable, the product absorbs moisture and gets soggy. Hence these packaging materials afford least protection to the product. Plywood boxes and waxed corrugated cartons are also used for packing large quantities. High density polythene woven gusseted bags laminated with 100 gauge low density polythene are suitable for packaging dried fish. HDPE is impervious to microbial and insect attack. HDPE is a material which will not spoil even if it gets wet. It is hard and translucent and has high tensile strength.

Table.1. Bulk packaging materials and their properties

Type	Merits	Demerits
Waxed corrugated cartons	Handy, light, hygienic and presentable	Very delicate, Not foolproof against insects, rodents, moisture, breakage
Dealwood or Plywood boxes	Compact and strong, Larger quantities can be packed, handling , transportation and stacking are easy, Can be reused, Protection against damage	Comparatively heavy, Cost is high, Cheap wood not easily available
Bamboo baskets	Handy, light, Not costly	Very delicate, Not foolproof against insects, rodents, moisture, breakage
Gunny bag	Light, handy, cheap, proof against breakage	Not foolproof against insects, rodents, moisture, Not hygienic
Dried palmyrah and coconut palm leaves	Cheapest of all and readily available in the coastal regions of India	Not foolproof against insects, rodents, moisture, Not hygienic and does not give good appearance, Packing is laborious
Multiwall paper sack lined with 300 gauge LDPE	Hygienic, presentable and can be printed	Costly, polythene lining may break during handling and hence is not foolproof against insects, rodents, moisture

HDPE woven gusseted bags laminated with 100 gauge LDPE	Hygienic, presentable and can be printed, Stackable, can be packed uniformly	

In the consumer market the dried fish is packed in low-density polyethylene or polypropylene. Due to the high moisture content of about 35 % in certain salted fishes they are often attacked by microbes. Hence fish should be dried to a moisture level of 25 % or below. Packets of different sizes and weights ranging from 50g up to 2 kg and bulk packs are available. Nowadays monolayer and multilayer films, combination and co extruded films are used for bulk packing and consumer packaging of dry fish. Polyester polythene laminates and thermoform containers are used to pack dried prawns and value added dried products.

Table 2: Consumer packaging of dry fish

Material Composition	Merits	Demerits
250 gauge low density polyethylene film	Cheap, readily available, good bursting and tearing strength and heat sealability	High water vapour and gas transmission rate, easy to puncture due to sharp spines, smell comes out. Shelf life limited.
250 gauge polypropylene film	Cheap, readily available, good bursting and tearing strength and heat sealability	High water vapour and gas transmission rate, easy to puncture due to sharp spines Shelf life is limited.
300MXXT Cellophane/150 gauge LDPE	Very low water vapour and gas transmission rate, transparent, good bursting and tearing strength , heat sealability and long shelf life.	Prone to easy attack by insects, costly.
12 micron plain polyester/150 g low density polyethylene	Very low water vapour and gas transmission rate, transparent, good bursting strength, puncture resistance & heat sealability. No insect penetration	Costlier
20micron Nylon laminated with 150 gauge polyethylene	Very low water vapour and gas transmission rate, transparent, good bursting strength, puncture resistance & heat sealability. No insect penetration	Costlier

In consumer packaging 100 to 700 gauge LDPE and PP were found suitable for storing dry fish. It also showed that dry fish when packed in films of higher gauge remained in good condition for a longer period. This is mainly due to the low water vapour transmission rate and oxygen transmission rate, which decrease with increase in thickness. In the case of overall quality 200, 300 and 400 gauge LDPE films also showed promising results. The advantages of

low density polythene are clarity, low water vapour transmission rate, good bursting and tearing strength and heat sealing capacity. The main disadvantage is the high gas transmission rate which is undesirable in dried fish packaging because the smell dissipates to the surrounding atmosphere.
Dry shell on prawns are packed mostly in duplex cartons or polystyrene trays and then covered with a laminate film. This is mainly due to the fact the spines will puncture the packaging material. Polypropylene pouches of 300 gauge are recommended for salted fishery products with moisture content of 35% and above for obtaining a shelf life of 6 months. The advantages being good clarity, Low WVTR, good bursting strength and tearing strength. Currently laminate films of Polyester/polythene are mostly used for packaging of dried fish. Polyester films are capable of giving good mechanical strength and reverse colour printing can also be done. Polythene is heat sealable and has good food contact application. The keeping quality of dry fish can be enhanced in an air-conditioned room where the temperature and humidity is low.

Dry fish is irregular in shape and size leading to great difficulty in packing. The have spines and projections which may puncture the packaging materials. In the case of jute bags because of its permeable nature, salted fish may absorb moisture depending on the relative humidity of the environment. In the coastal place where RH is always above 80 % this invariably takes place making the fish wet. Thus a suitable packaging material will ensure protection against migration of moisture and oxygen, and odour and insect attacks.

3.7. Accelerated freeze dried (AFD)

AFD products demand a very high price in the export trade. The final moisture content of AFD products generally is about 2 %. Low moisture content and large surface area make these foods extremely hygroscopic. Most dried products deteriorate when exposed to oxygen. Changes in colour may also take place as a result of bleaching. Light accelerates oxidative reactions and hence contact with light should be prevented. If proper packaging materials are not used there is every chance that the materials may undergo flavour changes due to the oxidation of the product and also migration of flavour from the packaging material. Since, fish contains fat there may be also a chance of it taking up the taints from the packaging material. The particular structural properties of freeze-dried products lead to damage by mechanical means. The light porous nature causes them to be very fragile and easily prone to breakage during handling and transportation. Freeze dried products are also liable to damage caused by free movement within the package. Measures must be taken to fit the product compactly in the container, while leaving the minimum headspace for filling inert gas.

Rigid containers both glass and cans were used earlier for packaging of freeze dried products. However, now metallised polyester laminated with polythene or aluminum foil /paper/polythenes are used since they have low oxygen transmission rate and water vapour transmission rate. Most of the packages are filled with an inert gas. The product can also be packed under vacuum to give better protection against damage.

Packaging of thermal process fish products

Retort pouches consist of three or four layers consisting of an outer polyester layer, a middle aluminum layer and an inner cast polypropylene layer. Aluminium foil is the barrier layer which gives the product a longer shelf life. Polypropylene has a high melting point of about 138°C and is used as the inner layer to provide critical seal integrity, flexibility, strength, taste and odour compatibility with a wide range of products. The different layers are held together with adhesives which are usually modified polyolefins such as ethylene vinyl acetate (EVA). Some pouches contain polyvinylidiene chloride, ethylene vinyl alcohol or nylon instead of the aluminium layer to permit viewing of the product. These are foil free laminated materials. These plastics are good barriers to oxygen molecules but are not complete barriers and therefore the shelf life is reduced. There are mainly two types of retort pouches viz, preformed and pouches which are made from laminates on the process line. Preformed retort pouches are more commonly used and they are filled manually or by using automatic filling machines. Sauces and curry products are packed instantaneously in pouches that are produced from laminated rolls which are simultaneously formed, filled and sealed. In case of products with solid contents, either pouch are filled with solids together with some liquid and sealed using a vacuum sealing machine. Once the product is filled and sealed it is then subjected to temperatures of 121.1°C with counter pressure so that the cold point or slowest heating point within the food reaches the predetermined time temperature integral.

Fish pickles

Fish pickle is a value added item whose bulk is contributed by low value items like ginger, chilly, acetic acid etc. Generally low cost fish, clam meat is used in fish pickles. Conventionally glass bottles are used as containers, which offer properties like inertness, non-toxicity, durability, non-permeability to gases, moisture etc. But they are heavy, prone to break, voluminous and expensive. New flexible packaging materials developed for fish pickle is based on plain polyester laminated with LDPE-HDPE Co-extruded film or Nylon/Surlyn or LD/BA/Nylon/BA/Primacore. These are inert to the product, can be attractively fabricated as stand up packs and can be printed on the reverse side of the polyester film.

Fish soup powder

Fish soup powder is a speciality product containing partially hydrolysed fish, protein, carbohydrates, fat and several other seasonings including salt. The product is hygroscopic and hence the selection of the package assumes great significance. Appropriate package developed for such products are 12 micron plain polyester laminated with LDPE-HDPE co-extruded film or 90-100 micron LD/BA/Nylon/BA/Primacore multilayer films which ensure a safe storage of the product up to six months.

Extruded products

Ready to eat breakfast cereals, pasta, ready-to-eat, snacks, pet foods, and textured vegetable protein (TVP) are prepared by the extrusion process. An extruder consists of one or two screws rotating a stationary barrel and the mixed raw material is fed from one end and comes out through a die at the other end where it gets puffed up due to the release of steam. It is either in the ready to eat form and hence have to be hygienically packed for consumption. The extruded products are highly hygroscopic in nature and hence they should not come into contact with moisture. Since the extruded product contains fat, the product should not be exposed to air. It is also highly brittle and may powder when crushed. Hence packaging films of high barrier strength and low permeability to oxygen and water vapour are required. Generally extruded products are packed in LDPE/metallised polyster laminated pouches flushed with Nitrogen.

Surimi and surimi based products

Surimi is an intermediate product / raw material for processing several value added products like fabricated foods, shrimp and crab analogues and a variety of other products. Surimi requires to be preserved frozen until used for processing different products. surimi is generally frozen as rectangular blocks. In order to prevent oxidative rancidity and desiccation care has to be taken to ensure that the frozen block does not contain any voids and that the packaging materials used have low water vapour permeability and low permeability to gases and odours. The packaging materials employed should be sufficiently strong and durable to withstand stress during handling, storage and distribution. LDPE and HDPE packaging films employed for block frozen shrimp are considered safe for surimi.

Fish Sausage

Fish sausage is a minced based product. Surimi is the base material, which is homogenised after mixing with several other ingredients. The homogenised mass is stuffed in synthetic casings like Ryphan (Rubber hydrochloride) or Kurehalon (Vinylidene chloride). The casing is closed using metal rings after which it is heated in water at 85-90°C and then slowly cooled. After drying the sausage is wrapped in cellophane laminated with polythene. Fish sausage is kept at refrigerator temperatures for retail; however when prolonged storage is needed it is better kept frozen. Fish sausage is also processed in polyamide and cellulose and fibrous casing. For thermal processing polypropylene casings are used so as to withstand high temperatures.

Glucosamine hydrochloride

D-Glucosamine hydrochloride is used to cure rheumatic arthritis, and is also used as an additive in the food & cosmetic industry. D-Glucosamine hydrochloride Powder is stored in a cool and dry well-closed container, the temperature should be lower than 25°C, and the relative humidity should not exceed 50%. Glucosamine is packed in polybottle, namely PP or HDPE of 1kg, 500g and 20 g, 1kg metallised bag, 25kg in drums for commercial use and smaller quantities are packed in auto sample vials.

Chitin and Chitosan

Chitin and chitosan are derived from prawn shell waste and is exported in large quantities. The product should be protected against moisture gain as well as microbial and insect attacks. Bulk packaging of chitosan is done in HDPE woven gusseted bag laminated with 100 gauge LDPE liner. Chitosan is also marketed in capsule forms for consumption. Capsules made of gelatin are used for filling chitosan. Since chitosan is in the powdered form or flakes they are filled into the capsules. A particular numbers of capsules are then placed in HDPE containers.

Fish Hydrolysate

Fish Hydrolysate is prepared from fish mince which has contain oil and is undiluted, and so is a richer food source for beneficial microbes and especially beneficial fungi in the soil. It is generally cold-processed and hence retains the amino acids and protein chains as such. Fish hydrolysate is concentrated, and when diluted can be used ideally as soil fertliser, and is suitable for all soils, crops, ornamentals, trees and vegetables It contains a wide spectrum of major nutrients and trace elements in organic, plant available form. It can be used as a foliar spray, but since the oil is present it may show patches on the leaves. The liquid is generally packed in jars or cans which are made of polypropylene or HDPE.

Fish Meal

Fish meal is a source of high quality protein (60%) and is also a rich in omega-3 essential fatty acids EPA and DHA due to the high fat content. Incorporation of DHA and EPA in fish meal will in turn ensure its concentration in the diets of fish and poultry, ultimately reaching the human diet. Hence the packaging should be impermeable to moisture, oxygen and other insets and pests. Fish meal is generally packed in HDPE sacks for bulk transportation. The fishmeal whether in ground or pelletised form should contain moisture 6-12 %. The fat content should not exceed 18% and the final meal should contain at least 100 ppm antioxidant (ethoxyquin). If the temperature exceeds°130 F or 55° C then the ventilation should be kept on hold. The fish meal is generally packed in jute bags, multiwall paper bag which are lined with polythene and in HDPE woven bags with liner.

Fish oils

Fish oils are highly unsaturated and easily susceptible to oxidation when exposed to air. Hence they have to be packed in containers which have high barrier properties which are moisture proof, oil resistant and impermeable to oxygen. Larger quantities of fish oil are mainly packed in LLDE/Nylon films or in glass bottles. Bulk transportation food grade flexitanks made of 4 layered polyethylene and tubular PP. Advantages of using flexitanks are that they can carry 50% more than bottles and therefore will save on storage space, packaging and transportation cost.

Fish oil is also marketed for regular oral dosage in the form softgel capsules. The shell is made of gelatin, water, glycerol or sorbitol. The process of encapsulation is by using the rotary die encapsulation process. The encapsulation process is a FFS operation. Two flat gelatin ribbons manufactured on the machine are brought together on a twin set of rotating dies that contain recesses in the desired size and shape, these cuts out the ribbon into a two-dimensional shape, and form a seal around the outside. At the same time a pump delivers a precise dose of oil through a nozzle incorporated into a filling wedge whose tip sits between the two ribbons in between two die pockets at the point of cut out. The wedge is heated to facilitate the sealing process. The wedge injection causes the two flat ribbons to expand into the die pockets, giving rise to the three-dimensional finished product. After encapsulation, the soft gels are further dried depending on the product. They are then further packed in glass or plastic bottles. The soft gels are also packed as blister packs.

Fish silage

Fish silage is a product made from whole fish or parts of the fish which are mainly processing discards and to which an acid is added. The liquefaction of the fish is brought about by enzymes inherent in the fish. The product is a stable liquid and contains all the water present in the original material. Hence it is in the liquid form. Fish silage is generally stored in huge drums or polycontainers so that they can be transported.

Shark fin rays

Dried shark fin is a traditionally exported item from India. Significant value addition is possible if the rays from the shark fins are extracted and exported in place of shark fins. With the indigenous development of inexpensive and simple technology for extraction of fin rays, export of fin rays have picked up. Moisture resistant packaging having good puncture resistance and sufficient mechanical strength to withstand the hazards of transportation are the major requirements in the packaging employed for shark fin rays. Polyester / polythene laminates or Nylon based co-extruded films having good puncture resistance are appropriate for shark fin rays. Traditionally dried shark fins are packed as bulk pack in jute sacks. The improved bulk pack consists of high-density polythene woven sack or polypropylene woven sack.

Suggested Reading

1. Gordon L. Robertson (2006). Food Packaging -Principles and Practice, CRC Press, Taylor and Francis, Boca Raton, FL.
2. Kerry. P.J (2013). Advances in meat, poultry and seafood packaging. Woodhead Publishing Ltd. UK.

18. Non-thermal processing of fishes

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Non-thermal preservation of food

- Conventional thermal processing results in some undesirable changes in food, such as loss of nutritional components that are temperature-sensitive, change in the texture of food due to heat, and changes in the organoleptic characteristics of food.
- 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. Hence it offers an alternative to conventional thermal processing.

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.

Preservative action of high hydrostatic pressure (HHP)

- 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.
- Inactivation of common bacteria requires higher pressure (300-600 MPa).
- The most baro-sensitive are bacterial spores that were found to survive pressures up to 1200 MPa at room temperature.
- HHP can bring about a significant decimal decrease in the population of pathogenic Gram-negative bacteria, Gram-positive bacteria, yeast, and mould and helps in food preservation for a longer duration.

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- The reduction in microbial load depends on the pressure and temperature during treatment. It also largely depends on the type of food processed.

Effect of high-pressure processing on food quality

- Food, when subjected to HHP treatment, undergoes high pressure for a short duration of time.
- The pressure applied to food during treatment is in the range of 200–700 MPa.
- The quality in terms of nutritional components, sensory, and texture of HHP-processed food is excellent since the food is exposed to treatment conditions for a very short period of time. Hence, HHP-treated food shows fresh-like attributes.

Merits

- HPP technology can be applied in processing foodstuffs that are either solid or liquid.
- The technology involves less-to-no utilization of food preserving agents & relatively low amounts of energy.
- Once the operational pressure has been attained, there is usually no extra energy needed to uphold the pressure.
- Compared to the conventional heat-utilizing technologies, HPP does not require supplementary energy to cool the food product beyond the estimated treatment period.
- The transmission and pressurization fluid (water) can be reused with zero-emission of wastes and hence it can be considered as one among the eco-friendly types of non-thermal food processing techniques compared to thermal pasteurization.
- Moreover, HPP can retain the taste of food, its nutrient composition and elongate its shelf-life. Thus, the spoilage rate can be decreased, which can help raise the economic value of the food commodity.

Major applications in seafood

1. Post pack lethality intervention for RTE seafood
   - *Cold post-packaging pasteurization*: For shelf-life extension, keeping freshness, maintaining higher sensorial qualities, functional properties and improving food safety.
2. Low pressure process application
   - *Mollusc shucking*: In HPP, the muscle, which is responsible for closing the shell, will not be able to contract and the oyster will open. This exposes the meat for easy extraction, resulting in a significant yield increase.
   - *Crustacean meat extraction*: In HPP, meat of crustaceans such as lobster or king crab will contract and detach from the shell, facilitating extraction with yield of almost 100 %.

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. Delayed growth of Enterobacteriaceae and H2S producing bacteria was observed in HP treated samples.

- 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 the conventional cooking. A high pressure of 250 MPa was given to pink perch mince samples added with and without MTGase enzyme, for a holding time of 12 min and a setting condition of 25 °C for 30 min was given prior and after the treatments. 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. High-pressure treatment and pomegranate peel extract did not influence significantly the colour and textural properties of cooked chicken nuggets. Thiobarbituric acid reactive substance values significantly ($p < 0.05$) increased in pressure-treated nuggets. Microstructural studies revealed shrinkage in the structure and loosening of the dense network of meat emulsion due to high-pressure treatment. Pressure treatment resulted in a reduction of 2–3 $\log_{10}$ cfu/g in total plate count and *Enterobacteriaceae* count.

- Kundukulangara Pulissery et. al. (2021) compared the textural and nutritional profile of high pressure and minimally processed pineapple. Changes in the pineapple quality in terms of texture, colour, total flavonoids, total polyphenols, vitamin C and sensory properties were investigated within the domain of 100-300 MPa and 5-20 min. 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 16th 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. The apparent reduction of microflora with pressure level was clearly evident from the diversity indices. A diminished piezotolerance of Gram-negative spoilage bacteria was also observed.

Limitations of HHP processing

- During processing, the organoleptic characteristic of HHP-treated food can be changed. This can be attributed to the ability of HPP to destabilize functional proteinaceous macromolecules, such as enzymes, by ionic and hydrophobic–hydrophobic interactions.

- HPP can accelerate lipid oxidation of treated seafoods during storage. This is caused by the release of inorganic transition metal ions from their respective compounds during the HPP process.
- HPP gives fish products a cooked appearance at high pressure (>200 Mpa).
- HPP can induce the formation of formaldehyde, which induces protein crosslinking, thus causing an increase in the hardiness of the treated fish. This is a drawback when HPP is employed for seafood treatment.

- *Types of food and HHP processing*
  - Foods with entrapped air or with insufficient low moisture content will be crushed or compacted under high pressure.
  - HHP is not suitable for
    - Solid foods with air included (Bread and cakes & Mousse)
    - Packaged foods in completely rigid packaging (Glass packaging & Canned foods)
    - Foods with a very low water content (Spices, Dry fruits &Powders)

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.

PEF device

- A typical PEF device consists of a food treatment chamber, a control system, and a pulse generator.
- The food is kept in the treatment chamber in between two electrodes generally made of stainless steel.

Applications of PEF in fisheries field

- PEF improves water holding properties of fish (submitting the fish muscle to PEF made its structure more porous)
- PEF technology improves extractive effectiveness to obtain protein from mussel (Improved extraction yield of protein)
- It can be used as a pre-treatment for drying

- PEF can be used to valorize by-products from fish processing industries.
- High-intensity PEF has been identified as an improved a method to extract calcium & chondroitin sulphate from fishbone.
- PEF has been tried for extraction of collagen from fish waste.
- PEF enzymatic-assisted extraction has been used for isolation of the abalone viscera protein.
- PEF can be used as a pre-treatment for fish waste for enhancing the yield of the extraction process.

Advantages of PEF processing

- PEF processing maintains the physical, organoleptic and functional characteristics of the final product, i.e., causing minimal changes in the flavour, vitamins, and other nutrients.
- It controls the presence of microorganisms in foods in a fast and homogeneous way
- Reduced process time
- Low energy consumption
- Continuity of the process
- Efficient and eco-friendly method
- Extended shelf life of the food product

Limitations of PEF processing

- The high initial capital investment is the main barrier that limits the application of PEF in the fish processing industry at this moment.
- PEF is a continuous processing method that may not be suitable for solid food products that cannot be pumped. Therefore, the conveyor is important to include in the design of the machine.
- In addition, inefficiency of this technique against the reduction of naturally occurring enzymes in the fish is another shortcoming of this emerging technology.
- The electrical conductivity of the product is a crucial parameter that limits the application of PEF to materials with moderate conductivity. PEF processing is limited to food products with low electrical conductivity and no air bubbles.

3. Irradiation/Radiation processing

- 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.

Two approaches to irradiation

1. Use of radioactive isotopes, such as Caesium or Cobalt: Isotopes produce penetrating gamma rays and require expensive facilities with heavy shielding, because the radiation is always on and could pose a hazard to workers.
2. Electrically generated radiation, such as X-rays or electron beams: Electrically generated radiation has less penetration strength and so is only useful for surface sterilization or on thin products. However, it is safer and less expensive to use, because it is turned on and off as needed and does not require shielding.

Agri-food applications of irradiation

Radicidation and Radurization: Refer to these applications of less than 10 kGy doses.

- Radurization: Application of an ionization dose sufficient to preserve the quality of food by ensuring a substantial reduction in the number of spoilage bacteria.
- Radicidation: Application to the food of a dose of ionization sufficient to reduce the specific number of viable pathogenic bacteria to a level such that they are not detectable by any known method. This term also applies to the destruction of specific parasites.

Radappertization: Application of high dose (10 to 60 kGy) of ionization to food in order to reduce the number and/or activity of living microorganisms so that none (except viruses) is detectable by any recognized method. Such radio-sanitized products can then be stored for up to 2 years at room temperature in sealed plastic packaging.

Table 1: Dose requirement in various applications of food irradiation

Dose Level	Dose	Applications
Low	<1 kGy	▪ Inhibition of sprouting of potato, onion and other tubers ▪ Insect disinfestation in stored grain, pulses and their products, dried fruits such as dates and figs ▪ Destruction of parasites in meat and meat products
Medium	1–10 kGy	▪ Shelf-life extension of fresh meat, poultry and seafood by elimination of vegetative bacteria responsible for spoilage ▪ Elimination of pathogenic organisms from meat, seafood and poultry ▪ Treatment for quarantine purposes of fruits and vegetables

High	>10 kGy	▪ Hygienization of spices, vegetable seasonings, etc. ▪ Sterilization of food for special requirements ▪ Shelf stable foods without refrigeration

Labelling requirements

- For ionizing radiation, information concerning its application to the food and/or one of the ingredients of the food is mandatory.
- This may be in the form of label statements such as "product treated by ionizing radiation", "product treated by ionizing energy", "product treated by irradiation" or affixing of the international symbol "radura", which indicates the existence of such treatments. However, the use of radura symbol is voluntary.

Merits

- It is among the non-thermal preservation methods with minimum effect on the quality, taste, appearance, and texture of foods.
- Ionizing radiation acceptability elevates as the consumer desire for minimally processed and yet safe food increases.
- The effectiveness of ionizing radiation is not only against destroying microbial entities and inhibiting pathogenic/spoilage bacteria; but also inhibiting insects, mites, and pests.
- The application of ionizing radiation has been shown as an alternative technique to detoxify aflatoxin present in foodstuffs.
- The processing time of ionizing radiation is reasonably less, considered as eco-friendly as well as leaving no chemicals/residue.

Demerits

- Excess accumulation as a result of constant exposure to irradiation is a major threat for the processors or workers.
- Some amino acids can be cleaved by high-dose irradiation, thereby changing the flavour and aroma of foods.
- Lipid oxidation is enhanced in the irradiated product since irradiation can accelerate auto-oxidation of lipids, producing hydroperoxides and off-flavours in food, especially seafoods rich in polyunsaturated fatty acids.

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 12^{th} day. However, electron beam irradiated sample had extended shelf life of 15-23 days with respect to dose level.

4. Ultraviolet (UV) Radiation

- A very economical non-thermal technology
- Non-heat technique for decontamination for improving both the shelf-life and safety of foodstuff.
- It is basically used to reduce the microbial load on the surface of food materials that are indirectly exposed to radiation, because of its low depth of penetration.
- 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.

Effect UV-C on microbes

- 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.

UV-inactivation dose (mJ/cm^2)

- Bacteria: 1–10
- Yeast: 2–8
- Fungus: 20–200
- Protozoa: 100–150
- Algae: 300–400

Factors affecting the efficiency of UV-C radiation

- The source and dose of the UV radiation
- The duration by which the product is exposed
- The nature of the foodstuff
- The alignment of the apparatus
- The nature of the microbe

Applications in the fisheries sector

- For food products, UV-C light technology application has been mostly confined to liquids and free-flowing foods.
- UV light is used in the fish industry to decrease the microbial load and increase the shelf life of fish, reduce the microbiological load in fish meal, disinfect working surfaces, and to sterilize the water in aquaculture and wastewater facilities.

- However, to achieve a more effective reduction in bacterial load, the studies indicate that UV light should not be used as a stand-alone strategy, but integrated with other technologies.

Merits

- The lethality effects of UV radiation against microbes are higher compared to the conventional chemical agents, for example, hydrogen peroxide and chlorine.
- Moreover, UV radiation is easy to utilize (user friendly) and cost-efficient.
- It has minimal effects on the quality of foods as it enhances sensory features such as taste for certain foods.
- It prevents recontamination as it can be applied in already packed food products.
- It is environmentally friendly.
- It can be used not only for liquid foods, but also for solid ones.
- Its processing time described as shorter and it also exhibits outstanding permeation capabilities to foodstuffs.

Limitations

- Accelerated senescence and surface discoloration in seafood can occur and deteriorate the treated seafood.
- UV radiation can induce oxidation of lipids in treated seafoods since hydrogen peroxide, superoxide radicals, and lipid radicals are indirectly formed by UV light.
- Peroxide created during extended UV light treatment can diminish the pigments and the fat-soluble vitamins.
- Cross-linking and fragmentation of protein, carbohydrate cross-linking, and peroxidation of unsaturated fatty acids in ultraviolet-treated seafood can be induced by superoxide radicals.
- Protein, aromatic amino acids, and enzymes are denatured by UV radiation, which could affect the composition of seafood.
- Consumers seem to be worried about the fact that UV radiation might be leading to radioactive materials in foods, which may subject them to serious health issues.
- Additionally, huge investment requirement is also a limiting factor for achieving the complete feasibility of the UV radiation process.

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.

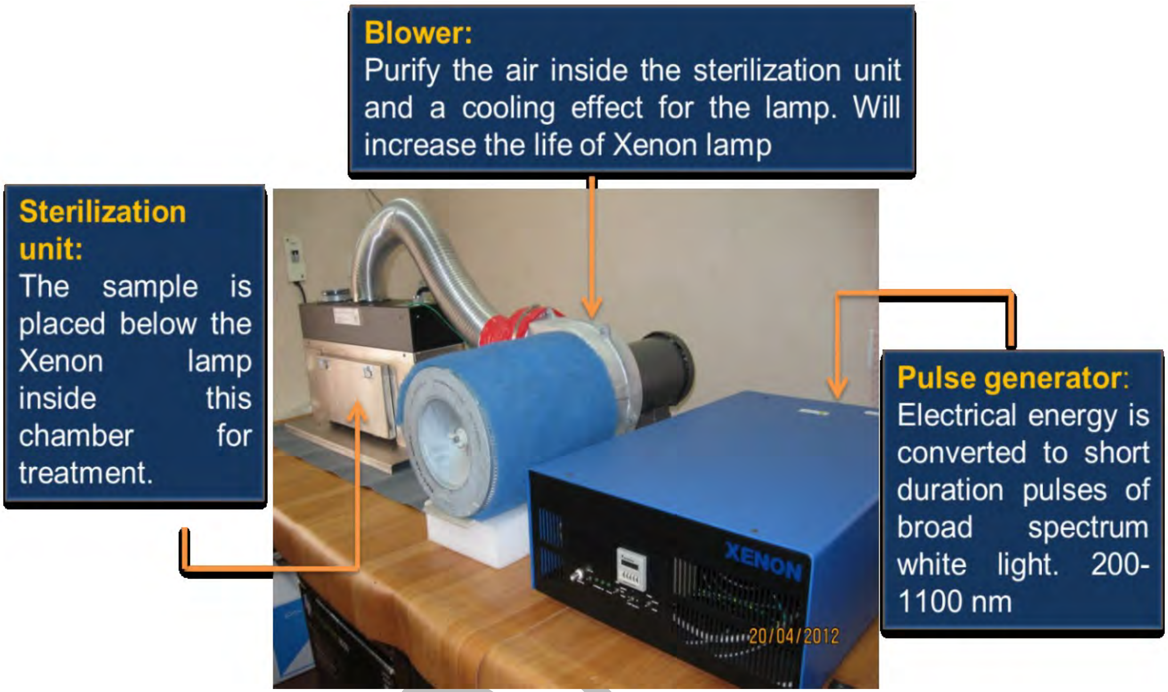

Figure 1: Pulsed Light Equipment of CIFT

Studies at ICAR-CIFT, Kochi

- Ananthanarayanan et. al. (2019) studied effect of pulsed light (PL) treatment on the shelf-life extension of yellowfin tuna (*Thunnus albacares*) steaks stored at 2±1 °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.

Merits

- PL serves as a rapid disinfection food processing technology.
- In addition, it exhibits much less damage to the nutritional content of foodstuffs that it has been applied to.
- PL is also shown to ensure microbial inactivation while at the same time retaining the foodstuff's sensory characteristic with fewer losses in terms of quality.
- The technology boasts a huge advantage compared to UV radiation by exhibiting an outstandingly short time energy transmission.
- Furthermore, besides the fact that PL exhibits a substantial reduction of bacteria in an exceptionally short time; it has huge adaptability, and is eco-friendly.

- Consequently, after PL application, the threat due to food-inherent disease-causing microorganisms is decreased; the shelf-life of foods increased as well as a promised enhanced economic return especially during the transportation period.
- In addition to that, PL has demonstrated promising results in the prevention of contamination of packaged products; the treatment is known to be applied even when the food is within the packages.

Demerits

- Similar to UV technology, the pulsed light comes with huge capital/costs in order to achieve successful investment.
- Pulsed light has been shown as not suitable for application in foods that are opaque and irregularly shaped, as they can be potential habitats for bacteria proliferation.
- Moreover, extended periods of treatment in PL can result in a "heating effect" upon food products and in the end affect the effectiveness of the bacterial destruction.

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.

Method of application of ultrasound

- *Ultrasonic horn*: Horn is dipped in the liquid solution or juice and is treated with certain treatment frequency.
- *Ultrasonic bath*: Food material or packaged food is kept and the sound waves are generated in a bath that creates ultrasound effect and brings about desired changes in food.

Applications in the seafood industry

Freezing

- Improves freezing by better preservation of the microstructure; Requires less time and small crystal size; Improved diffusion & Rapid decrease in temperature.

Thawing

- Reduction in thawing time; Preserve colour; Inhibits lipid oxidation; Improved product quality & Reduced product dehydration.

Brining/Pickling

- Low water activity and longer shelf life; Require less sodium chloride & Uniform distribution of salt in less time.

Drying

- Intensification of mass transfer; Shorter processing time; Enhanced organoleptic properties & Increased drying rate due to less resistance.

Merits

- Eco-friendly, green technology
- Ultrasound has successfully proven its potential in the food sector in various critical areas like;
  - -Food preservation
  - -Extraction
  - -Intensified synthesis
  - -Improvement of the physical and chemical properties of food.
- Production of a better-quality product at lower temperatures, with an improved rate of heat and mass transfer.

Demerits

- The very limited technical information about ultrasonication.
- Ultrasound, when applied at high intensities generates heat due to an escalation in temperature, which has detrimental effects on the organoleptic and nutritional characteristics of the food product.
- Lack of consumer awareness about ultrasonic-processed food.

7. Cold Plasma (CP) Technology

- Plasma: Fourth state of matter after solid, liquid, and gas.
- When the energy of gases crosses a certain value, it results in the ionization of gas molecules.
- Ionization of gas molecules gives rise to plasma.
- Two types
  - -Thermal plasma
  - -*Cold plasma* (non-thermal)
- 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.

Cold plasma generation

- 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.
- Methods
  - -Radio frequency plasma
  - -Dielectric barrier discharges

-Gliding arc discharge
-Microwave
-Corona discharges

- Cold plasma is an ionized gas generated through gas ionization under corona discharge, dielectric barrier discharge, microwaves or radiofrequency waves.

Advantages & Applications

- Reduction of the microbial load in food or on the surface of food. All kinds of microbes are said to be inactivated by cold plasma technology, including viruses, fungi, and bacteria.
- Enhance the physical and chemical properties of food constituents like lipids and proteins.
- Sterilization of food processing equipments.
- Inactivation of food spoilage enzymes.
- Treatment of food packaging material. Cold plasma can serve for in-package sterilization.
- Treatment of wastewater.
- Cold plasma is produced at near ambient temperature and does not depend on high temperature for microbial inactivation.
- Since the temperature used is ambient, there are no chances of thermal damage to heat-sensitive food material.
- It has continually been referred to as an eco-friendly technique since, besides having minimal changes on the food matrix, its application does not result to the generation of toxic residuals/wastes.

Limitations

- Treatment with CP can induce lipid oxidation in fatty foods and other food products susceptible to oxidation. This may lead to the creation of short-chain fatty acids, aldehydes, hydroxyl acids, and keto acids, thus causing off-flavour and off-odour during storage.
- Undesirable textural properties, acidity, and discoloration of treated food can occur.
- Also, surface topography can be influenced by plasma treatment.
- The high cost of installation is also a major drawback.

8. Ozone treatment

- Ozone is a colorless gas with a typical odor.
- It contains three molecules of oxygen and is chemically written as O_3. It is formed when molecular oxygen (O_2) combines with singlet O.
- Ozone is a very reactive gas, and it is very much unstable and cannot be stored and needs to be produced on the spot when needed.
- 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.

Effect of ozone on microbes

- 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

Merits

- GRAS (Generally Recognized as Safe) chemical with US FDA approval, as well as an antimicrobial additive for direct contact with foods.
- Ozone cleans and disinfects better than chlorine because of the latter's relatively low inactivation rate owed to concentration limitations posed by regulations.
- It can be used in gas form or it can be mixed with water to form ozonated water.
- Ozone has very great biocidal activity at reduced contact times.
- The lower energy consumption is worth mentioning as a strong merit.

Limitations

- Although ozone treatment can prolong the shelf-life of seafood by reducing the microbial load, pre-treatment with ozone can induce oxidation in seafood. This may cause it to smell or taste less palatable to consumers.
- Due to the enhanced protein oxidation induced by ozone, the functionality of protein in seafood can be decreased, leading to poor-quality products.
- Ozone is one of the strongest oxidizing agents widely used for disinfection of wastewater and removal of organic substances and offensive odour. There is usually a high risk of post-contamination, since ozone can only lower the microbial load before and during treatment but has less effect on prevention of contamination after treatment.

Other methods

Acidic Electrolyte Water

- Electrolyte water (EW) is made from water without the addition of any hazardous chemicals except sodium chloride.
- EW is known as either a sanitizer (EW containing HOCl, an acidic electrolyte water) or a cleaner (EW containing NaOH, an alkaline electrolyte water.
- The simplicity of EW production and application is the foremost reason for its popularity.
- In numerous fields such as medical sterilization, agriculture, food sanitation and livestock management, EW is gaining attention because of its antimicrobial properties.

Dense phase carbon dioxide (DPCD)

- DPCD processing utilizes the liquefied carbon dioxide and performs at mild temperature and relatively low pressure, about one tenth of the pressures for HHP.
- It is applied to cold pasteurize and extend the shelf life of product without heating.
- Carbon dioxide is a nontoxic, non-flammable and low-cost gas; in the supercritical state, the fluid CO_2 rapidly penetrate porous materials due to its low viscosity ($3–7 \times 10^{-5}$ Pas) and surface tension. This penetration is accompanied with pH decrease, bicarbonate ion generation and cell disruption, which contribute to the microbial and enzyme inactivation.

High voltage electrical discharge (HVED) processing

- Different from PEF in electrode geometry, shape of pulses and mode of actions, HVED generally consists a needle electrode and a grounded one (normally flat geometry) or wire plane.
- Though the advantages of PEF and HVED are promising, the release of metals from the corrosion or migration of electrode materials should be concerned and investigated in the future applications.

Non-thermal food preservation methods: Future Prospects

- Non-thermal treatments are among the most focused research areas in the food sector due to consumer demands for safe and nutritious food free from microbes.
- Despite the active studies on the innovation and improvement of the discussed non-conventional technologies, conventional processing is still dominant in food/fish processing.
- There are still a lot of barriers before the scaling up of the non-conventional technologies in food industry, such as the huge equipment and installation cost, and complex operation process.
- It is very important for the food industries to fully understand the respective action mechanisms as well as merits and demerits of non-thermal food technologies before and even during their implementation.
- Streamlining the process mechanisms of each technique and consumer education about the strengths and prospects of non-thermal technologies could help to raise awareness, prior to considerations on how to amend their designs, if their cost-effectiveness and scale-up capacity for industrial-level applications are to be improved.
- Deep evaluation of the processing line *via* hazard analysis and critical control points (HACCP) methodology to enhance and sustain the improved food hygiene, quality and safety processes.
- Cost comparisons of the selected non-thermal food processing technologies to choose the suitable technology that meets the food production requirements based on the capacities and operational needs.
- When a target food industry that operates at either small-, medium- or large-scale desires to implement a specific non-thermal food processing technology, the prerequisites already prescribed by the manufacturers should be adhered to, despite the

variations in facilities/equipment, operational/production scales, intended food product(s), factors of production, as well as consumer targets.

- Developing a hurdle-like non-thermal technology that combines a number of processing methods, designing the intended equipment particularly for large scale application as well as formulating the rules and regulations governing the intended foodstuff safety when using these technologies should be among the future priorities for the food industry and its stakeholders.
- Overall, the clear advantage of these technologies, especially in right combination, makes them a promising approach for inactivation of microorganisms while maintaining sensory attributes and nutritive value.

Conclusion

The demand from consumer for safe and nutritious food products has promoted the rapid development of non-conventional processing technologies. 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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19. Seafood handling and curing techniques

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Curing is a collective term for salting, drying and smoking as a means of preserving fish. , has been practised perhaps longer than any other food preservation technique. Its being the oldest and cheapest methods of fish preservation is still widely practiced in many parts of the World. These techniques are applied as single or in combination. In the current market situation both wet and dry cured fishery products have commercial importance. Advances have been made in this regard for process standardizations to meet the current demand of the market. Cured fish consumption is more practiced in areas where the availability of fresh fish is comparatively limited viz., interior markets as well as hilly areas. This method is also widely adopted in coastal areas when an excess catch is to be preserved for later utilization during the lean season or for marketing to other areas, thereby assuring its seasonal as well as regional availability.

Drying

The term 'drying' implies the removal of moisture by means of evaporation. Water being the essential component for all living organisms, its removal facilitates microbial retardation, arrest of autolytic activity as well as oxidative changes and hence can be used as a method of preservation. In any process of drying, the removal of water requires an input of thermal energy. The thermal energy required to drive off moisture can be obtained from a variety of sources, e.g., the sun or the controlled burning of oil, gas or wood, electrical heating etc. The thermal energy can also be supplied directly to the fish tissue by microwave electromagnetic radiation or ultrasonic heating. In fish, water constitutes about 70-80% and removal of this constituent to a level that arrests the unfavorable microbial and oxidative activities facilitates its effective preservation.

Drying phases

In foods, there exist three layers of water viz., an adsorption layer, a diffusion layer and a free layer. Water at the adsorption layer, also referred to as the bound water is tightly bound to the particle and hence does not take part in any chemical reactions. The second layer being the diffusion layer is less tightly bound and the third layer consists of free water which has all the properties of ordinary water. Free water involves in all chemical reactions and favors the growth of microorganisms and hence is important in the drying process. Water activity is the measure of the free water available and lowering of this water activity is essential for effective preservation.

During air drying, water is removed from the surface of the fish and water moves from the deeper layers to the surface. Drying takes place in two distinct phases. In the first phase, whilst the surface of the fish is wet, the rate of drying depends on the condition (velocity, relative

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humidity etc.) of the air around the fish. If the surrounding air conditions remain constant, the rate of drying will remain constant; this phase is called the 'constant rate period'. Once all the surface moisture has been carried away, the second phase of drying begins and this depends on the rate at which moisture can be brought to the surface of the fish. As the concentration of moisture in the fish falls, the rate of movement of moisture to the surface is reduced and the drying rate becomes slower; this phase is called the 'falling rate period'.

Constant rate drying phase

During this period the rate of drying is dependent on several factors:

Air temperature: At the beginning of drying, the heat energy required for evaporation is balanced by the heat supplied by the surrounding air. Warm air can provide more heat energy and, provided that the air speed and relative humidity will allow a high rate of water movement, the rate of drying will be increased.

Relative humidity of the air: The lower the relative humidity of air surrounding the drying area, the greater the ability to absorb water and the faster the rate of drying.

Air velocity*:* Air velocity has a positive relation with rate of drying. Better the speed of the air over the fish, the greater will be the drying rate. The air around fish consists of an immediate stationary layer above the fish, a slowly moving middle layer and an outer turbulent layer. On saturation of the immediate stationary air layer, the moisture passes into the slowly moving middle layer. The higher the air speed in the outer layer, the thinner the slow moving layer, allowing more rapid movement of water away from the fish.

Surface area of the fish: the larger the surface area, the faster the rate of drying. By scoring and splitting the fish, the surface area increases relative to the weight/thickness resulting in the rate of drying to be faster.

Falling rate drying phase

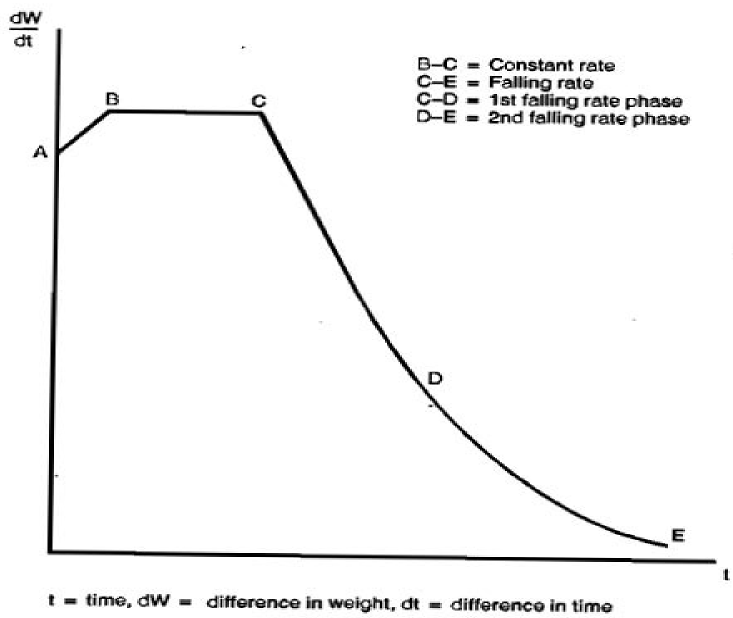
As drying progresses, the water evaporates from the fish surface and is replaced by the water from the interior of the muscles by diffusion. This process is comparatively slower which limits the drying rate and is referred to as the falling rate phase. Drier the product is, slower will be the diffusion of water to the surface. Several factors influence the rate of drying at this phase:

Nature of the fish: a high fat content in the fish retards the rate of drying.

Thickness of the fish**:** the thicker the fish, the further the water in the middle layers has to travel to reach the surface, slowing down the drying rate.

Temperature of the fish**:** diffusion of water from the deeper layers to the surface is greater at higher temperatures.

Water content**:** as the water content falls, the rate of movement to the surface layers is reduced.



Drying rate curve.

Source: Redrawn from *FAO Fisheries Report*, No. 279. Food and Agriculture Organization of the United Nations, Rome. 1983.

Methods of Drying

There are basically two methods of drying fish. The common and traditional method being sun drying which is done by utilizing the atmospheric conditions viz., temperature, humidity and airflow. 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. In sun drying, there is no control over the operational conditions and hence generally the losses viz., quantitative as well as qualitative ones, cannot be substantiated. Hence it is essential that the operations be controlled to get a product with superior quality as well as stability. Recently, the controlled artificial dehydration of fish has been developed so that fish drying can be carried out under controlled conditions.

Natural or sun drying:

In this type solar and wind energies are utilized as the source of energy.

- Drying on the ground
- Rack Drying
- Solar drying using Solar tent dryers, Solar cabinet dryers

Artificial / Mechanical Dryers

- ***Hot air dryers***

- Cabinet dryer
- Tunnel dryer
- Multi deck tunnel

- ***Contact Dryers***
  - Vacuum dryers
  - Rotary dryers
  - Drum dryers

Salting

Salting, one of the traditional methods of preservation is usually done alone or in combination with drying or as a pretreatment to smoking. The presence of sufficient quantities of common salt (sodium chloride) in fish can prevent or drastically reduce bacterial action. Salting amounts to a process of salt penetration into the fish flesh when fish is placed in a strong solution of salt (brine) which is stronger than the solution of salt in the fish tissue. Penetration ends when the salt concentration of the fish equals that of the surrounding medium. This phenomenon is known as osmosis. It is based on different factors like diffusion and biochemical changes in various constituents of the fish. This process facilitates preservation of fish by reducing the water activity. A concentration of between 6–10 % salt in the tissue together with the removal of some water from the tissue during the salting process will prevent the activity of most spoilage bacteria. If fish are salted before drying, less water needs to be removed to achieve preservation. A water content of 35–45%, depending on the amount of salt present, will often prevent, or drastically reduce, the action of bacteria.

Salt

Source

Common salt, in its purest form consists of sodium chloride (NaCl). However almost all commercial salts contain varying levels of impurities depending on the source and method of production.

Based on the source as well as method of manufacture, common salt can be grouped as:

- ***Solar salt:*** prepared by the evaporation of sea or salt lake waters by the action of sun and wind.
- ***Brine evaporated salts:*** produced from underground salt deposits which are brought to the surface in solution form and is heat evaporated.

- ***Rock salt:*** obtained as natural deposits from interior rock mines which are ground to varying degrees of fineness without any purification.

Chemical composition

Commercial salts vary widely in their composition with best quality salt containing upto 99.9 % sodium chloride, whereas low quality salt may only contain 80 % sodium chloride. The main chemical impurities of commercial salts include calcium and magnesium chlorides and sulphates, sodium sulphate and carbonate, and traces of copper and iron. Apart from these, contaminants such as dust, sand and water may also be present in salt. Presence of calcium and magnesium chlorides even in small quantities tends to slow down the penetration of salt into the flesh and hence their presence may lead to increase the rate of spoilage. Further magnesium chloride is hygroscopic and tends to absorb water, making the fish more difficult to dry and to keep dry. Calcium and magnesium salts give a whiter colour but tend to impart a bitter taste. Very often the consumer demands a whitish colour in salted fish products and small quantities of calcium and magnesium compounds in the salt are usually considered desirable. Excessive quantities, however lead to a bitter flavour and the dried product tends to be brittle which can cause problems during packaging and distribution. Trace quantities of copper in salt can cause the surface of salted fish to turn brown affecting the appeal of dried fish.

Microbiological purity

Many commercial salts, particularly solar salts, contain large numbers of salt tolerant bacteria (halophiles) and counts of up to 105/g have been recorded. A group of halophiles, also referred to as the red or pink bacteria, can be a problem in commercial fish curing operations as they cause a reddening of wet or partly dried salt fish. Halophilic moulds tend to grow on dried fish under favourable conditions causing the formation of dark patches called 'dun'. They tend to occur more frequently in rock salt.

Physical properties

Fine grain salt dissolves more rapidly in water and is preferred for making brines. However on direct application of fine grain salt on fish causes a rapid removal of water from the surface which becomes hard and prevents the penetration of salt to the inside of the fish, a condition referred to as 'salt burn'. Hence for dry salting, a mixture of large and small grain sizes of salt is recommended.

Types of Salting

- ***Dry salting:*** This is the most widely used method of fish curing. Dry salting is advisable for fishes of any size, except fatty fishes. The fish is gutted, beheaded or ventrally split open and the viscera removed followed by washing. Scoring is also practiced if the flesh portion is thick for facilitating better salt penetration. Salt is then applied in the ratio 1:3 to 1: 10 (salt to fish) depending upon the size of the fish. The fish is then stacked in clean cement tanks or other good containers layered with salt and weight is applied from top for better salt penetration. The fish is kept in this condition for 24-48 hours. After salting period, the fish is taken out, washed in brine to remove adhering salt and drained. It is then hygienically dried to a moisture content of about 25%. Yield of the product by this method is about 35-40% with a storage stability of upto three months under ambient conditions.

- ***Wet salting:*** The initial stages of processing and salting are the same as for dry curing. However the fish kept in tank is allowed to remain in self brine till marketing without further drying. For marketing, as per the demand the wet salted fish is drained and packed in palmyrah leaf baskets or coconut leaf baskets. This method is particularly suitable for fatty fishes like oil sardine, mackerel etc. Wet salted fishes have short shelf stability with a moisture content of 50-55% and a salt content of around 25%.

- ***Pickle salting:*** Pickle curing is a type of wet salting where the fish is layered by granular salt 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.

- ***Kench salting:*** In this method, salt is rubbed on to the surface of the fish and stacked in layers of salt and fish. The self-brine formed is allowed to drain away. 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.

- ***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.

Quality issues in dried and salted fish

- ***Pink/Red:*** Salt content prevents the growth of normal spoilage microflora in the fish but halophiles, which can survive at 12-15% of salt concentration, will survive. Halophilic bacteria are present in most of the commercial salt. A particular group of halophiles called Red / Pink cause reddening of wet or partially dried salted fish. These do not grow in brine or in fully dried fish. They are aerobic and proteolytic in nature, grows best at 36ºC by decomposing protein and giving out an ammoniacal odour. Spoilage appears on the surface as slimy pink patches. However these bacteria are not harmful in nature. Usage of good quality salt is recommended to avoid this condition. This spoilage is mostly found in heavily salted fish and absent in unsalted fish.

- ***Dun:*** In salted fish, brownish black or yellow brown spots are seen on the fleshy parts, referred to as "dun". This is mainly caused by growth of halophilic mould called *Sporendonema epizoum*. This gives the fish a very bad appearance. Moulds usually grow at relative humidity above 75%. The optimum temperature for growth is 30-35 ºC. 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. Chemical method of prevention includes dipping the fish in a 5% solution of calcium propionate in saturated brine for 3-5 minutes depending upon the size of the fish.

- ***Salt burn***: A mixture of large and small grain sizes is recommended for dry salting of fish. If fine grain is used directly on the fish, salt burn may occur due to the rapid removal of water from the surface with no penetration of salt to the interior of the fish.

- ***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.

- ***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 hydroxy 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.

- ***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. Beetles attack when the moisture content is low and especially when the storage is for a long time. The commonly found beetles are *Dermestes ater, D frischii, D maculates, D carnivorous* and *Necrobia rufipes*. The larva does most of the damage by consuming dried flesh until the bones only remain. Mites are also an important pest, which are found infesting dried and smoked products. *Lardoglyphus konoi* is the commonly found mite in fish products. Infestation can be reduced by proper hygiene and sanitation, disposal of wastes and decaying matter, use of physical barriers like screens, covers for curing tanks etc, and use of heat to physically drive away the insects and kill them at 45 º C.

- ***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.

Improved Method developed for salt drying of fish by ICAR-CIFT

The fresh fish landed is immediately washed in clean sea water to remove slime, adhering dirt, etc.

- These are then taken to the fish curing yard where very strict care is to be taken to maintain hygienic conditions and quality of material. Unlike in the traditional method, all further processing work should be done on carefully cleaned tables to avoid contamination with sand, dirt etc.

- It is advisable to use chlorinated water (2-5 ppm) for all these cleaning operations of fish. The contact surfaces can be washed with chlorinated water of 100ppm.

- On the processing tables, the fish is dressed, removing the viscera. In the case of fishes like sardines etc. it is advisable to remove the scales also to improve the appearance of the final cured product. The fishes can be cut from the dorsal side to form butterfly shape. This will help to reduce the size of fish and help in faster drying. The viscera should be immediately removed to the waste baskets kept under the tables. In the case of small fishes, where this is not practicable commercially, fish is salted directly after cleaning it well.

- The dressed fish is then washed in good quality water and the water is allowed to drain completely. This can be easily done in perforated plastic containers.

- After complete draining, the fish is taken to the salting table where good salt is applied to the fish uniformly by hand. Care must be taken to keep the hands of workers clean for this operation. In general, the salt-to-fish ratio can be 1:3 (one part salt to four parts fish) for larger sized fishes. The ratio varies to 1:6 for medium sized and 1:10 for smaller sized fishes.

- After salting, the fish is stacked in very carefully cleaned cement tanks and kept for at least 24 hours in these tanks. After this, the fish is taken out and just rinsed in brine with a minimum of 15% salt to remove excess solid salt adhering to its surface.

- The salted fish is then dried in clean drying platforms. The drying can be done in driers at 55^{o}C for 8hrs. The fish must be dried to moisture content of 25% or below.

- At every stage, extreme care must be taken to maintain proper standards of hygiene.

Drying of shrimp

- Wash the shrimp in potable water thoroughly to remove the dirt and contaminants on the surface of shrimp. Chlorinated water of 2-5ppm can be used.
- Take water in a container and bring it to boil. (Minimum of 80^{o}C)
- Add 10% salt and 0.1% citric acid to it. The weight of salt and citric acid is calculated in a weight/volume manner. Eg: for 1litre water 100g salt and 1g citric acid can be added.
- Take shrimp in containers with holes in it. Take care to spread shrimp in thin layer
- Dip the container with shrimp in the hot water for 10 seconds till a light red/pink colour appears. The increase in time of dipping will cook the shrimp and lead to loss of quality of dried shrimps.
- Drain the water. Spread the shrimp on any clean surface so as to reduce the temperature.
- Keep the shrimp for drying at 55°C for 6-8 hrs so as to reduce the moisture content to ~15%.
- The dried shrimp can be hygienically packed and stored at room temperature.

Advantages of the CIFT method

- The method is very simple and can be easily adopted by the common man.

- It prevents contamination with harmful bacteria and enhances the storage life of the cured fish considerably.

- It is comparatively a very cheap method. Considering the enhanced shelf life and increased price that can be realised by curing fish by this method, the slight increase in the cost of production can be treated as negligible.

Smoking of fishes

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.

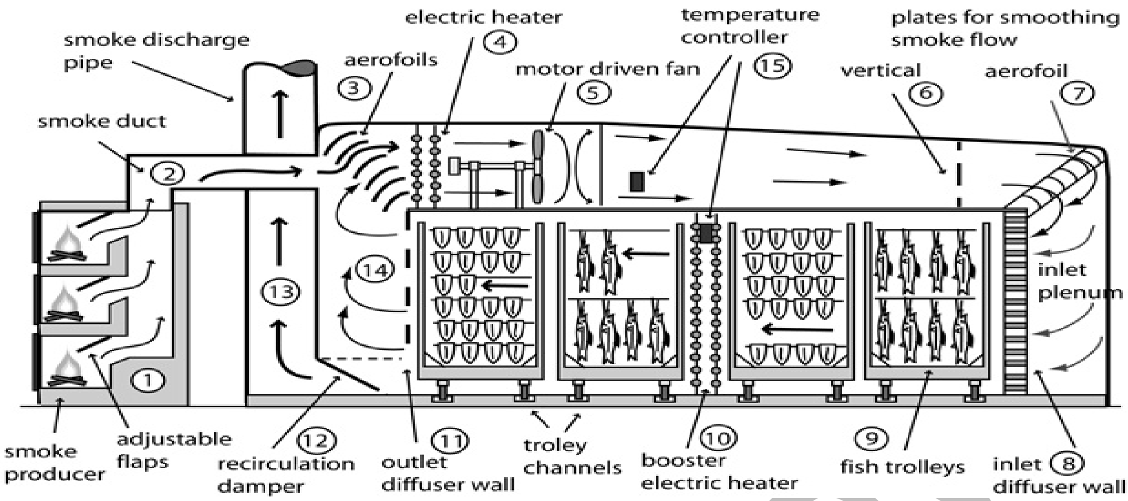


Fig. Illustration of the hot smoke airflow in the Torry smoking kiln

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.

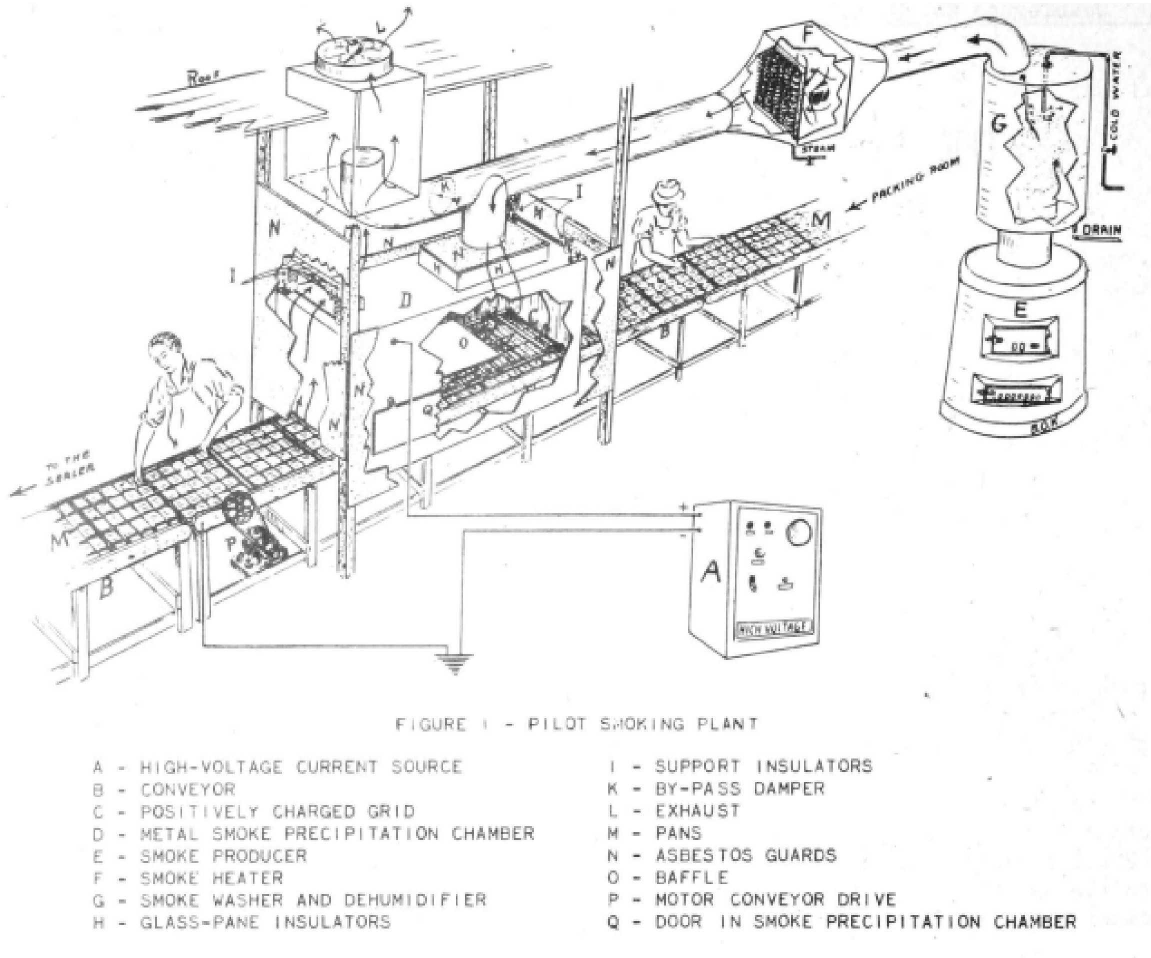


Fig. Schematic diagram of Electrostatic smoking with basic components.

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.

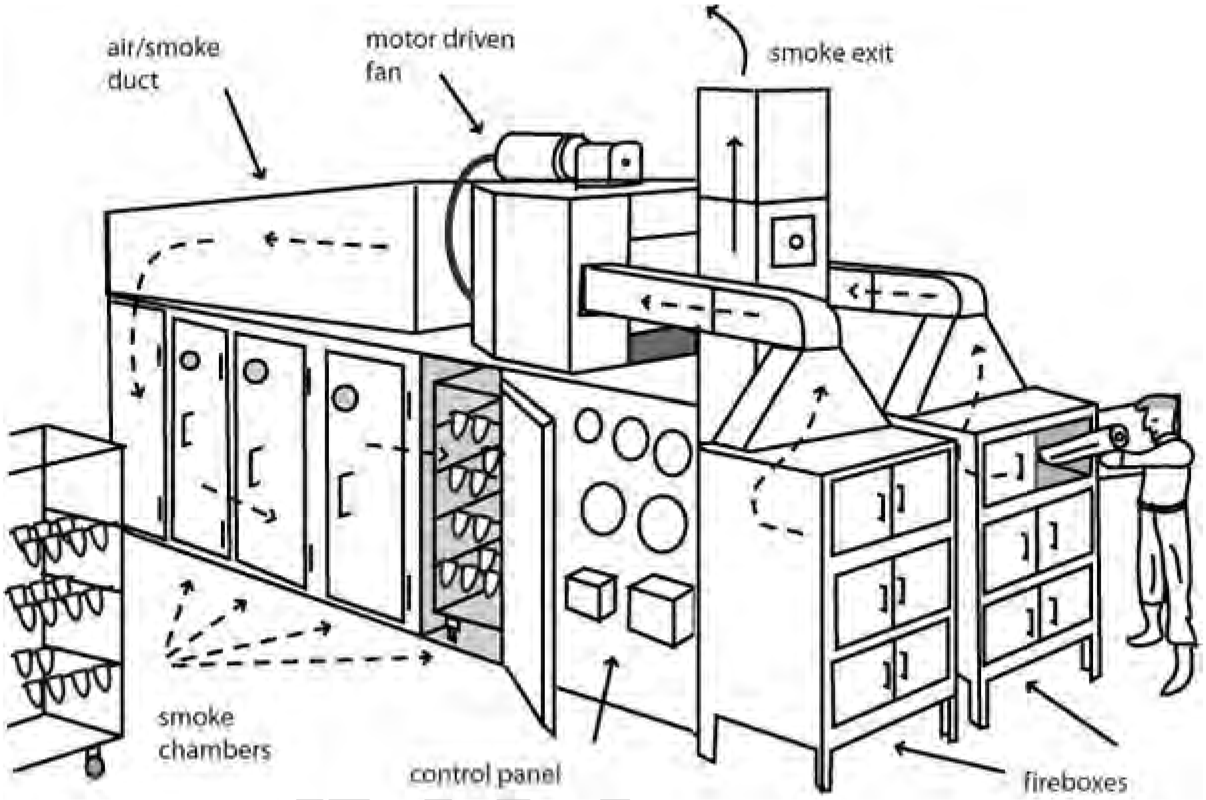


Fig. Smoking kiln

Potential hazards associated with smoking of fish

I. Biological hazards

Generally, Cold smoking will typically reduce the level of microorganism by 90 to 99%. But after the cold smoking there is no such steps to eliminate or reduce the level of microorganisms. Typical temperature used for cold smoking is 22-28º 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.

II. Chemical hazards

1. Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are large class of organic compounds containing two or more fused aromatic rings made up of carbon and hydrogen atoms. Incomplete combustion (pyrolysis), during smoking can lead to formation and release of PAHs into the smoked product. Some of them are carcinogenic and mutagenic substances causing serious health issues to the consumers. Processing procedures such as smoking, drying, roasting, baking, frying and barbecuing/grilling can lead to formation of PAHs in food items. Many reports indicate that individual PAHs in smoked fish can go up to a level of 200µg/Kg. Among the 33 PAHs evaluated by the scientific committee on Food (SCF, 2002) of EU, 15 were found to be having mutagenicity/Geno toxicity in somatic cells of be 2µg/Kg wet weight and 12µg/Kg in meat of smoked fish and fishery products, 5µg/Kg and 30µg/Kg in smoked sprats and 6µg/Kg and 35µg/Kg in smoked bivalve mollusc respectively.

2. Histamine:

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

3.Biotoxins:

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

III. Physical Hazards

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

IV. Other potential hazards associated with smoking of fish

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

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20. High value byproducts from fish processing discards

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Aquatic food consumption at global scale increased at an average annual rate of 3.1% from 1961 to 2018 with the per capita annual consumption value from 9.0 kg to 20.5 kg. There are various factors contributes for this increment. One of the factors is awareness among the consumers about the health benefits of consuming fish and its richness in terms of nutritional value. Fish is considered as nature's superfood as it is not only the source of high-quality proteins (well balanced amino acid composition and high digestibility), it is also a rich source of therapeutic fatty acids (Poly Unsaturated Fatty acids) and unique source of essential nutrients (essential amino-acids, essential fatty acids, minerals and vitamins). Another important factor is the growth in global fish production and indirectly the availability. It is projected that by 2030, around 62% of global fish consumption will be met by farm raised fishes, which was only 49% in the year 2012. The contribution by farm raised fish to consumption increases while contribution by wild caught category decreases (51% in 2012 and projected to be 38% by 2030).

The raise in fish consumption drives the growth in fish processing and associated sector. On the other hand, fish is a highly perishable commodity due to low connective tissue content, low glycogen reservoir, near neutral postmortem pH, nature of post-mortem autolytic process, nutrients density and high moisture content. Processing of fish is highly essential in order to preserve its nutritional value and wholesomeness and to make it available across the continents. The processing activities lead to generation of various parts of the fish as by-products/processing discards. Discards generated from fish and shellfish includes scale, skin, bone, visceral mass, belly flaps, fins, exoskeleton and head waste from crustacean, shuck-water from clams and oysters, meat washed water from surimi industry, ink-gland, beak and tentacles from cephalopods, reproductive organs, etc. The quantity of discards generated during fish processing may vary from 30-75% of raw material weight depending on the type of processing, type product and type of raw material. Some of the products and quantity of waste generation is presented in Table 1. Globally around 32 million tones of fishery raw material is estimated to be wasted in the form of processing discards.

When not addressed properly, fish processing discards turn to be a huge issue from the perceptions of resource underutilization, resource wastage, economical loss and environmental destruction. On the other side, when it is properly used, fish processing discards can be a potential solution to achieve the sustainability in fisheries, to improved food and nutritional security, to achieve the global economical growth, for being healthy people and to preserve the healthy environment and this blue planet. Globally, fish waste management is a serious issue and fish waste utilization has become an objective of global governing policies laid down by various international organizations.

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Table 1. Waste generation during industrial processing

Products	Waste Generation (%; w/w)
Shrimp products	50
Fish fillets	65
Fish steaks	30
Whole and gutted fish	10
Surimi	70
Cuttle fish rings	50
Cuttle fish whole	30
Cuttle fish fillets	50
Squids whole cleaned	20
Squid tubes	50
Squid rings	55

Biochemical nature of fish processing discards

In terms of biochemical composition, fish discards are very close to the edible fish meat portion. The quanity of constituents are almost same, but the quality differs as the nature and type of molecules and their proportions in the discards are different. For an instance, scale, skin bone and fins are rich source of the connective tissue proteins particularly the collagen fraction is high. Similarly, the meat in head portion, cutting residues (cutting dusts), filleting frame waste meat are rich in structural proteins including myosin, actin, troponin, tropomyosin etc.

Table 2. General composition of fish discards

Nutrients	Composition*
Crude protein (%)	57.9 ± 5.3
Fat (%)	19.1 ± 6.1
Crude fiber (%)	1.2 ± 1.2
Ash (%)	21.8 ± 3.5
Calcium (%)	5.8 ± 1.3
Phosphorous (%)	2.0 ± 0.6
Potassium (%)	0.7 ± 0.1
Sodium (%)	0.6 ± 0.1
Magnesium (%)	0.2 ± 0.1
Iron (ppm)	100.0 ± 42.0
Zinc (ppm)	62.0 ± 12.0
Manganese (ppm)	6.0 ± 7.0
Copper (ppm)	1.0 ± 1.0

The wash water from surimi industry and shuck water from depuration of molluscs are rich source of water-soluble proteins (sarcoplasmic proteins) including albumins, globulins, and enzymes. Except bony part of fish discards, other waste parts are generally rich in protein accounts to 45-60% of raw material on dry weight basis. Next to protein the major constituent is lipid. Fish eyes, belly flaps, fish head, visceral mass are all rich source of lipids. On dry basis, fish discards in general contains around 4-20%. Fish bone and fish scale serve as rich source of fish calcium and phosphate. The general composition of fish discard is presented in Table 2.

With the continuous efforts from researchers across the globe, it has been possible to produce various high value products from fish processing discards. The following classification of possible products from fish discards may be considered for all the academic purpose.

Edible products

- Fish bone broth/soup
- Fish head stock
- Products from recovered meat from waste

Industrial products

- Fish oil
- Fish meal

Feed /Fertilizer

- Fish silage
- Fish manure/compost
- Fish protein hydrolysate
- Foliar spray

Specialty products

- Ambergris
- Fish Skin Leather
- Flavor Extract
- Caviar substitutes

Bio-functional/ health products/High value products

- Chitosan derivatives
- Collagen derivatives
- Fish protein hydrolysate
- Glucosamine
- Chondroitin sulphate
- Squalene
- Sulphated polysaccharides
- Hyaluronic acid
- Fish bone calcium
- Hydroxyapatite
- Pigments
- Enzymes

High value products from fish processing discards of commercial interest

In spite of enormous number of research reports, only very few products have been turned into commercial production. Fish collagen peptide, chitosan, PUFA, Astaxanthin, Squalene, Fish protein hydrolysates and bioactive peptides, fish/shrimp flavor extracts and fishbone calcium supplements are some of the examples for high value fish products produced from fish waste. High value products from fish processing discards of commercial interest with their market value and potential is presented in Table 3. The value addition to these discards may range from 2-20 fold of raw material cost. In some occasion, the fishery waste is considered as zero cost raw materials.

Table 3. High value products from fish processing discards of commercial interest with their market value and potential.

Raw material	Product	Value/Unit (USD)	Market growth projection
Skin/Scale/Bone	Fish collagen/Fish gelatin/Collagen peptide	10-50/kg	USD778 million – 2021 USD 1,137 million by 2026, CAGR of 7.9%
Crustacean shell waste	Chitosan	9-25/kg	USD 476.6 million-2016 SD 1,088.0million- 2022, CAGR-14.7%
Fish body/Liver	Fish oil/PUFA	10-100/kg	USD 1788 million-2021 USD 2623million- 2028, CAGR-5.6%
Shark liver	Squalene	20-260/kg	USD 129 million-2020 USD 184 million -2025, CAGR - 7.3%.
Shrimp/shellfish waste	Astaxanthin	60-300/kg	USD 1.33 billion-2020 CAGR-15.1%
Fish discards	Fish bioactive peptides/protein hydrolysate	5-50/kg	USD254 million USD 361.5 million -2027 CAGR-5.1% Market volume -50,278.3 tons
Shrimp waste	Shrimp flavor	5-10/kg	---
Fish viscera	Fish enzymes	---	---
Fish bone	Fish bone calcium	5-8/kg	---

There are practices in some parts of countries where the industry pays to the waste collector for taking the fish discards.

Proteins from secondary raw material and the possible industrial products

Fish processing discards are rich in fish muscle proteins (Myosin, actin troponin, tropomyosin etc.), connective tissue proteins (Collagen and its derivative gelatin), fish enzymes, hemoproteins and carotenoproteins. The relevant industrial products which exploit the above-mentioned proteins are fish protein concentrate, surimi from frame meat, fish meal, shrimp head meal, squid meal, dried fish scale and dried fish skin.

Table 5. The protein components from secondary raw material and the relevant possible industrial products

Proteins from secondary raw material	Protein rich industrial products from secondary raw material
• Fish muscle proteins (Myosin, actin troponin, tropomyosin) • Collagen • Gelatin • Fish enzymes • Hemoproteins • Carotenoproteins	• Fish protein concentrate/fish protein powder • Surimi • Fish meal • Shrimp head meal • Clam meal • Squid meal • Dried fish scale • Dried fish skin

Fish protein concentrate

Fish protein powder (FPP) is a dried fish product, meant for human consumption, in which the protein is more concentrated than in the original fish flesh. Different methods for the separation of meat from fish are employed, such as washing meat with water for two to 3 cycles and concentrating, solubilization of muscle by pH adjustment and iso-electric precipitation, solvent extraction to method to remove the fat, cooking and drying, and a combination of various methods. The raw material such as fish filleting frames, head waste, tuna red meat and belly flaps can be used to produce fish protein concentrate

Earlier studies conducted on rat have shown that fish proteins have greater cholesterol lowering ability (Ammu et al., 1989) and can protect the animal against lipid peroxidation. Fish protein reduces serum cholesterol, triglycerides and free fatty acids and increases the proportion of HDL cholesterol. In general, protein supplements claims to help weight loss and muscle building. Fish protein supplement have shown beneficial effects on blood levels of glucose and LDL-cholesterol as well as glucose tolerance and nutritional composition of body in overweight adults (Vikoren et al., 2013). In another study, dietary scallop protein completely prevented high-fat, high-sucrose-induced obesity whilst maintaining content of lean body mass and improving the lipid profile of plasma in male C57BL/6J mice (Tastesan et al., 2014).

Fish Collagen

Collagen is a structural protein found mainly in the skin and bones of all animals. Collagen is the most abundant protein originating from the animal source, comprising approximately 30% of total animal protein. It is composed of three α-chains which are intertwined to form a triple-helix. It is present in the connective tissue matrix that makes the framework of skin, bones and joints, cornea, blood ducts, and the placenta. There are many types of collagen, but 90% of our body's collagen protein is Type-I collagen. It is found to be rich in amino acids such as glycine, valine, alanine, proline and hydroxyproline (Burghagen, 1999). Glycine constitutes one third of the total amino acid content of collagen followed by hydroxyproline and proline, which account for another one-third. Owing to this structural uniqueness of collagen molecule, there is increasing interest for the direct consumption of collagen in the form of their easily digestible derivatives. Worldwide, this interest has been taken-up by the nutraceutical industry, especially in developing countries.

Currently, collagen is used in many pharmaceutical and cosmetic products, due to its structural role and better compatibility with human body. It is commonly used in the cosmetic industry for the production of skin lotions as it forms a superior protective film to soothen and hydrate the skin. Such potential of collagen has tremendous bearing on anti-aging treatment. Apart from that, collagen has a wide range of applications in the field of cosmetic and burn surgery, especially as dermal fillers in the reconstruction of skin and bone. Collagen gels have potential clinical importance in the preparation of 'artificial skin' used in treating major wounds. Injectable collagen hydrogels have been successfully used for soft-tissue augmentation, drug delivery carriers and hard-tissue augmentation. Microfibrous collagen sheets are used as promising drug carriers for the treatment of cancer. It is also an essential component in diverse orthopedic and dental treatments. Further, collagen is recently projected as a joint mobility supplement.

Fish Gelatin

Gelatin is a soluble polypeptide obtained by denaturing the insoluble collagen. Procedures to derive gelatin involve the breakdown of cross-linkages existing between the polypeptide chains of collagen along with some amount of breakage of intra-polypeptide chain bonds. Tissues that contain collagen are subjected to mild degradative processes, i.e., treatment using alkali or acid followed or accompanied by heating in the presence of water, the systematic fibrous structure of collagen is broken down irreversibly and gelatin is obtained. It is the only protein-based food material that gels and melts reversibly below the human body temperature (37°C). Gelatin possesses unique and outstanding functional properties and can be obtained in reasonable cost, make it one of the most widely used food and pharmaceutical ingredient.

Fish skins and bones can be utilized to produce gelatin, thus contributing to solve the problems of waste disposal with the advantage of value addition. The main drawback of the fish gelatins are the gels based on them tend to be less stable and have inferior rheological properties compared to mammalian gelatins. It may be noted that fish gelatin has its own unique properties like better release of a product's aroma and flavor with less inherent off-flavor and off-odor than a commercial pork gelatin, which offer new opportunities to product developers.

Fish enzymes

Fish visceral waste can serve as a source of large amount of enzymes which have potential applications in different sector starting from laundry application to pharmaceutical applications (Simpson and Haard, 1987). The nature of fish visceral enzymes is different from the enzymes found in the digestive system of terrestrial animals. Hence, they can be exploited for certain distinct applications. Fish pepsins can act even at low temperature and higher pH optimum than the pepsins from terrestrial source. Moreover, fish pepsins do not undergo autolysis at low pH (Raa, 1990). The differences in the properties of pepsins from fish and other sources could be attributed to the difference in the sequence and composition of aminoacids (Gildberg and 0verbj, 1990). Fish enzymes can be used as processing aids in the following applications

- Protein hydrolysates production
- In production of caviar from a variety of fish species
- for removal of squid skin
- for cleaning of scallop
- for descaling of fish
- coagulation of milk
- Cheese production

Hemoproteins

Hemoproteins are complex proteins, composed of a protein molecule and a non-protein compound (prosthetic group). Hemoglobin and myoglobin belongs to the category of hemoproteins involves in transport of oxygen in the blood and tissues of animals, respectively. The heme portion can be recovered from blood as well as muscles discards. The recovered material may be used iron supplement or as a chemical substrate for production of the cooked cured-meat pigment. During the production of hydrolyzates from meat, hemin could be recovered as by-product.

Carotenoproteins

Carotenoproteins and carotenoids are other classes of compounds found in the flesh and skin of fishes and in the exoskeleton of shellfish. They are not synthesized in their body. They are acquired through their food chain (Haard, 1992). Similar to hemoproteins, Carotenoids are also composed of a protein moiety and a non-protein prosthetic group. Isolation of carotenoproteins and carotenoids from shellfish processing discards has been reported (Long and Haard, 1988). Inclusion of caratenoids pigments in feed formulations of some of the aquacultured fishes and ornamental fishes shows the importance of these compounds in industrial applications (Shahidi et al., 1993).

Fish protein hydrolysates (Bioactive peptides)

Apart from being highly nutritious, fish muscle proteins can be made use for preparing fish protein hydrolysates which comprises of bioactive peptides with valuable nutraceutical and pharmaceutical potentials. Fish protein hydrolysates (FPH) are the mixture of amino acids and peptides obtained by digesting proteins from fish meat or fish processing waste with proteases.The size of these peptides may range from 2 to 20 amino acid residues with the molecular masses of <6000 Da and are highly bioactive. The food derived peptides can be used as functional food ingredients or as nutraceuticals to benefit the human health and prevent disease. In this context, large pharmaceutical companies are more interested to invest in bioactive peptide research to open therapeutic prospects.

Chitin

Chitin is a nitrogenous polysaccharide (poly N-acetyl Amino D- glucose) found in the outer skeleton of insects, exoskeleton of crabs and shrimps and internal structure of lobsters and other invertebrates. It is the most abundant organic compound next to cellulose in the earth. Chitin represents 14-27% and 13-15% of the dry weight of shrimp and crab processing waste respectively (Ashford et al., 1977). Chitin is present as chitin protein complex along with minerals mainly calcium carbonate. So the process of chitin production consists of deproteinisation with dilute alkali and demineralization with dilute acids. Chitin on deacetylation gives chitosan and on hydrolysis with concentrated HCl gives glucosamine hydrochloride. CIFT has developed technology for production of chitin, chitosan and glucosamine hydrochloride from prawn shell waste.

Carboxymethyl chitin

Carboxy methyl chitin is another value shot derivative of chitin. The conversion of chitin into carboxy methyl chitin came in to practice by carboxymethylation. It has successfully proved its use in the field of cosmetics as moisturizer, skin smoothener and a cleaner for face skin conditioning it is used for the preparation of food products also.

Chitosan

Chitosan is prepared by deacetylation of chitin. Chitosan is almost colourless, light in weight and soluble in dilute organic acids. Its uses are hindered due to its insoluble nature in water, alkali and organic solvents. It gives viscous solution when dissolved in dilute organic acids such as formic acid, acetic acid, citric acid etc. Chitosan finds extensive applications in pharmaceutical applications, food industries, chemical industries. Chitosan is used in dental and surgical appliances as a haemostatic agent, wound healing, biodegradable films as a replacement for artificial skins for removing toxic heavy metals, wine clarification, industrial effluent treatment, agriculture, photography, cosmetic applications and textiles and as an immobilizing agent for enzyme.

Glucosamine hydrochloride

Glucosamine is chemically glucose in which a hydroxyl group on the second carbon atom is substituted with an amino group. It crystalizes as glucosamine hydrochloride during purification under acidic conditions. It is one of the amino sugars used by biological systems for bringing modification to the functions of proteins

Glycosaminoglycans (GAGs)

Glycosaminoglycans (GAGs) are heteropolysaccharides consist of repeated unit of disachcharides and no branched chains. Out of two monosaccharides, one is always an amino sugar (N-acetylgalactosamine or N-acetylglucosamine) and the other one is an uronic acid (Ronca et al., 1998; Kogan et al., 2007). They are present in the extracellular matrix of all animal cell surfaces and their function is to regulate different proteins such as growth factors, enzymes, cytokines. They finds the applications in food, cosmetic and clinical areas. The identified potential sources of glycoconjugates include mainly the marine organisms like sponges, sea cucumbers, squids, mollusks. The matrix of collagen associated with proteoglycans, macromolecules having a core protein to which the GAGs (chondroitin sulfate, keratan sulfate, dermatan sulfate and heparan sulfate) are covalently bonded by means of a tri-saccharide linked to a serine residue and form the cartilage tissue (Seno and Meyer, 1963). Hyalurunic acid (HA) is the only non-sulfated GAGs and is not covalently bound to the protein in any tissue. Chondroitin sulphate (CS) and HA are the most valued GAGs in market because of its abundance in mammalian tissues and notable physiological functions and high activity (Imberty, 2007).

Chondroitin sulphate

Chondroitin sulphate (CS) consist of repeated disaccharide units of glucuronic acid (GlcA) and *N*-acetylgalactosamine (GalNAc) linked by β-(1→3) glycosidic bonds and sulfated in different carbon positions (CS no-sulfated is CS-O). The classification and type of CS is dependent on sulfate group placing: carbon 4 (CS-A), 6 (CS-C, more common), both 4 and 6 (CS-E), positions 6 of GalNAc and 2 of GlcA (CS-D) and 4 of GalNAc/2 of GlcA (CS-B). The function of the organism and tissue influence the composition (shark, CS-D; dogfish, CS-A and CS-D; squid and salmon, CS-A and CS-E; ray, CS-A and CS-C) and concentration (e.g., 9% in shark fin and 14% in chicken keel) of CS. Thus, CS from marine sources differs in chain length and over sulfatation (Vázquez, 2013).

Chondroitin sulfate involved in various biological processes such as the function and elasticity of the articular cartilage, hemostasis, inflammation, cell development, cell adhesion, proliferation and differentiation by being an essential element of extracellular matrix of connective tissues. Chondroitin sulfate with less than 20 kDa is orally administered in nutraceutical formulations indented to treat and prevent the osteoarthritis.

Hyalurunic acid

In marine organisms, the the eyeball of fish species is the only clear source of HA is present in the vitreous humor (VH). VH volume and HA concentration varied with the fish species, for instance, HA is obtained from eyeballs of shark and swordfish at 0.3 g/L from 18 mL of VH and 0.055 g/L from 70 mL, respectively (Imberty et al., 2007). HA is also present in the cartilage matrix as structural element and of the most researched benefits of hyaluronic acid is its ability to alleviate pain in joints. Its effectiveness in this area isn’t surprising since hyaluronic acid is especially concentrated in the knees, hips, and other moving joints. It is a major component of both cartilage and the synovial fluid that bathes these joints, binding to water to create a thick, gelatinous substance that lubricates and protects the cartilage. In addition to playing a vital role in joint health, another majo benefits of hyaluronic acid is its effectiveness at maintaining healthy, youthful skin. The reason is because hyaluronic acid is an essential component of the skin. The suggested oral dose of hyaluronic acid is 100–200 mg per day.

Omega-3 fatty acids

The health benefits of seafood have mainly been attributed to the marine lipids. The beneficial effects of seafood have traditionally been ascribed to the presence of omega-3 polyunsaturated fatty acids, particularly eicosapentaenoic acid (EPA) and docosa hexaenoic acid (DHA). The amounts of fatty acids most frequently found in seafood range between 8 and 12% EPA and between 10 to 20% DHA. These fatty acids accumulate in the fish muscle via the food chain from plankton. This arises from the fact that marine phytoplankton has a high ratio of EPA and DHA, and thus these fatty acids are accumulated in the food chain. These fatty acids have pleiotropic effects and influence the *in vivo* production of inflammatory components, blood rheology, and membrane functionality. Due to their potential effects in promoting health, recommendations for daily intakes of n-3 PUFAs have been published by several international scientific authorities several organization

Squalene

One of the most interesting compounds available from fish is Squalene which is found in deep sea sharks liver oils. Squalene is most abundant in the liver oils of deep sea sharks, commonly called spiny dog fish. The liver oil of these species contains about 40 to 85% squalene by weight of oil. Squalene is a polyunsaturated hydrocarbon, better known as an Isoprenoid or Isoprene. By virtue of its double bond structure attached to six Methyl [- CH3] groups the isoprenoid has an exceptionally strong antioxidative effect in cell metabolic activities

Fish bone calcium-Calcitone

It is well documented that consumption of whole small fish is nutritionally beneficial providing with a rich source of calcium. Calcium and phosphorus comprise about 2% (20 g/kg dry weight) of the whole fish. Small fish are often eaten whole, including bones. However, in the case of large fishes like tuna, bone is a major component of processing waste. Thus, the filleting wastes of tuna and other bigger fishes are very good sources for calcium when the quantity of calcium is concerned. Calcium derived from the filleting waste can be used for pharmaceutical purposes, as it is mainly in the form of calcium phosphate with ideal calcium-phosphorus ratio. Central Institute of Fisheries Technology, Cochin has optimised the process to extract from fish bone which is mainly treated as processing discard during filleting operation of larger fishes, viz tuna, carps etc. Before packing, the calcium powder was supplemented with vitamin D which is known to enhance absorption and bioavailability of calcium in the body. *In vivo* studies conducted at CIFT in albino rats have shown that fish calcium powder supplemented with vitamin D has improved the absorption and bioavailability. The product is packed in 400 mg capsules containing 200 mg calcium per capsule.

Carotenoid pigments in Shrimp

Studies on efficient utilization of shrimp industry byproducts have been concentrated mainly on recovery of chitin and chitosan from the waste. In recent years, much attention is being paid for extracting valuable constituents from shrimp waste like natural carotenoid pigments. The most prevalent carotenoid found in shrimp is astaxanthin, 3,3'-dihydroxy-i,i-carotene-4,4'-dione representing about 65-98 % of the total carotenoids present and consisting of 3 sterioisomers (3S,3'S; 3S,3'R; 3R,3'R). Three different forms of this particular pigment are recognized in crustaceans, namely diesters, monoesters and the free form. Normally, wild caught shrimps will have more pigmentation compared to their cultured counterparts. Highest carotenoid content was reported in the head of deep-sea shrimp (*A alcocki* 180-185 μg/g) and marine shrimp (*P stylifera* 150-155 μg/g) followed by *P monodon* (120-135μg/g), *P vannamei* (120-130μg/g). High levels of carotenoids were also reported in carapace of *A alcocki* (115-120 μg/g), S *indica* (117-120.0 μg/g) and *P stylifera* (100-105μg/g). Relatively low levels of carotenoids were reported in shrimp *P indicus* and fresh water prawn *M rosenbergii* and crabs. The major carotenoids in shrimps, fresh water prawn and marine crab was reported as astaxanthin and its esters. β-Carotene and zeaxanthin were reported at low levels in these species. Most of the carotenoids in shrimps are distributed in shell (nearly 84-87%) and only 12-15% is present in flesh. The recovered carotenoids can be used as colorants in food products, used as antioxidant and as pigment source in diets for ornamental fishes, farmed salmon and trouts etc. Carotenoids from shrimp waste can be used in prevention of cancer, enhancement of immune responses and improvement of visual function. Currently major application of carotenoids include nutritional supplements, pharmaceuticals, food colorants, and animal feed additives (Mohan et al., 2014).

Technologies Available for high value products with ICAR-CIFT

- Technology for edible value-added products from fish waste
- Technology for high protein snacks using fish discards based ingredients
- Technology for fish collagen peptide
- Technology for fish collagen/gelatin
- Technology for chitin and derivatives
- Technology for Astaxanthin
- Technology for melanin
- Technology for hydroxyapatite
- Technology for bioactive fish peptides
- Technology for fish protein hydrolysates
- Technology for fish bone calcium
- Technology for Squalene
- Technology for encapsulated fish oil powder

Conclusion

Globally, the aquatic food waste (secondary raw material) has been identified as source of high value functional ingredients. On the other hand current exploitation of aquatic food waste is happening as high volume low value products for example fish silage, fish meal, squid meal, shrimp head meal etc. The major high value products such as collagen and its derivatives, chitin and its derivatives, hydroyapatite and fish calcium, shrimp pigments and caratenoproteins are having a huge market potential. The way the fish waste utilized globally needs a rattled shift in order to realize the full potential of aquatic food processing waste generated.

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21. Utilization of fish waste for feed, manure and agricultural applications

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Fishery waste which forms nearly 50% of the total weight of fish landed is an environmental issue in the present scenario. The recovery of biomolecules for the development of various products helps to eliminate harmful environmental aspects and improve quality in fish processing sector in addition to enhancing the profitability of the industry. In this respect the experiments conducted at CIFT has shown that, production of fish silage, foliar spray and feed from fishery waste has great potential as a high-end product. However, there are certain practical difficulties in the implementation of the techniques for utilisation. The problems in collection and processing is hindered due to highly scattered nature of availability i.e., On board, Fish markets, Pre-processing centres and processing centres. For e.g. Kerala has nearly 150 exporting companies and more than 2400 pre-processing centres. The highly perishable nature is also a major problem of handling the fishery by products.

Fish silage

Fish silage is defined as a product made from whole fish or parts of the fish to which no other material has been added other than acid and the liquefaction of the fish is brought about by enzymes 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 requires oil separation. This involves expensive equipment and is suited to fairly large-scale operation. Almost any species of fish can be used to make fish silage though cartilaginous species like shark and ray liquefy slowly. Fish waste, cuttle fish/squid waste can be used for the preparation of silage. The production of silage involves preferably organic acids like formic acid (35kg/tonne) to preserve the fish and then allow the enzymes already present in the fish to liquefy the protein. When 3.5% formic acid is added to the fish the pH will be nearly 4. Mineral acids like sulphuric acid also can be used for this purpose. But in this case pH would be about 2.5, which requires neutralization before formulating feeds to the poultry or cattle. There is an alternate method of production of silage by fermentation. The fish is mixed with a carbohydrate source like molasses and lactic acid is produced in the system to reduce the pH by introducing a lactic acid producing bacteria like *Lactobacillus plantarium.*

Foliar spray

Foliar spray is a technique of feeding plants by applying liquid fertilizer directly to their leaves by spraying. Plants are able to absorb essential elements and nutrients through their leaves and absorption takes place through the stomata of the leaves and also through the epidermis. Movement of elements is usually faster through the stomata and this result in faster growth and flowering. Some plants are also able to absorb nutrients through their bark. The process of foliar spray preparation is by hydrolysing the fishery waste either by adding acid directly as in case of silage or by *in-situ* production of lactic acid by microorganisms. The clear upper portion of acid silage is decanted and suitable diluted and used as spray. In case of microbial process, the fish waste is mixed with a carbohydrate source like molasses and inoculated with lactic

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acid producing bacteria and the lactic acid produced will hydrolyse the protein partially. It will take 20-30 days for hydrolysis and the upper clear liquid can be used as foliar spray.

Feed from fish processing discards

Feed is considered as the major expense in fish farming, accounting for about 50–60% of the total variable costs. Preparation of feed for aquaculture and poultry is an important option for utilization of general, unsorted waste from industry as well as fish markets. There is a growing demand for pellet feeds, due to the increase in aquaculture activity. Feed is also a major input affecting water quality and subsequently effluent quality in culture ponds. Fish feed management includes several factors viz. choosing the right feed, using a correct feeding method, calculating the feeding cost and ensuring the cost effectiveness of fish farm. Currently, aquaculture accounts for 40.33% of the world's fish production. Fish frames and other discards contain significant amounts of muscle proteins. They have a better balance of the dietary essential amino acids compared to all other animal protein sources. About, 25% of the protein requirement for feed is met from fish waste

Table 1: Fat and protein content of discards from selected species

Fishmeal based Fish feed	Fat	Protein
Sardine fish	3.77	27.6
Sardine waste	7.62	27.70
Tilapia waste	3.58	28.18
Threadfin waste	3.67	28.81
Anchovy fish	5.89	27.10

Preparation of feed from fish waste

The proximate composition and characteristics of many processing wastes suggest that it can be converted directly into feed. Most of these protein sources can be converted to fish flesh, which in turn provides quality protein for man. Utilization of these wastes can be direct or indirect. In direct utilization, either the wastes can be used as such as in the case of meals; cakes etc. or it can be used with some simple processes like fermentation, silage preparation etc. In indirect utilization, the wastes can be utilized as a substrate for the growth of single cell proteins for example, and these secondary products can be included in feed with or without primary substrate.

Table 2: Nutritional composition of fish processing discards

Nutrient	Fish waste
Crude protein (%)	57.92 ± 5.26
Fat (%)	19.10 ± 6.06
Crude fiber (%)	1.19 ± 1.21
Ash (%)	21.79 ± 3.52
Calcium (%)	5.80 ± 1.35
Phosphorous (%)	2.04 ± 0.64
Potassium (%)	0.68 ± 0.11
Sodium (%)	0.61 ± 0.08
Magnesium (%)	0.17 ± 0.04
Iron (ppm)	100.00 ± 42.00
Zinc (ppm)	62.00 ± 12.00
Manganese (ppm)	6.00 ± 7.00
Copper (ppm)	1.00 ± 1.00

Values in % or mg/kg (ppm) on a dry matter basis.

Fish waste can be macerated into paste and prepared at farm site as meal and used for feed. Alternatively, fish waste may be initially converted to meal or silage, which later on can be made into feed after compounding with other essential nutrients like carbohydrate, fat, trace minerals and vitamins. A good amount of research work has focused on the replacement of fish meal in feeds by various processing wastes / byproducts. Fish soluble obtained as a byproduct of fish meal production also serves as an ideal protein source for animal feed. It is rich in B group vitamins and also contains unidentified growth factors. It also serves as an attractant in fish feed. Meals obtained from small prawns, prawn heads, mantis shrimp, crabs and krill is a potential ingredient for shrimp diet. It is reported that the crude protein level varies between 30-50% depending on species and the chitin content is 16%. Ash content ranges from 25- 40%. It is rich in cholesterol, carotenoid pigments, chitin, calcium, iron, manganese, choline, niacin, pantothenic acid and cyanocobalamine. The quality of the silage depends on the freshness of the raw material. Silage has chemo attractant properties due to the free amino acids. About 70 % of the total shrimp production ultimately gets transformed to waste. Replacement of fishmeal by shrimp meal is possible to the level of 10 -15%. Shrimp waste can also be ensiled. Crustacean silage has been found to exhibit feeding stimulatory properties in a variety of fish species. Squid waste which usually includes viscera may also contain head and tentacles, fin, skin and pen accounting for about 52% of the total weight. Squid processing wastes are important feed ingredients particularly in shrimp diets. Protein content ranges from 70 to 90 %. Squid meal has a fat content of 4 - 7 % which contains high content of highly unsaturated fatty acids. Squid meal has chemo attractant and growth promoting properties. Inclusion in aquafeeds upto 30 % level is possible. Fish silage may be ideally seen as a source of protein and several minerals in feed preparations. Infact, it partially replaces fish meal in feeds (typically 5-15%). Silage contains comparatively, high level of free amino acids and peptides, which improve the growth performance and better disease resistance.

Quality of animal feed

Apart from nutritional composition, the quality of animal feed may be expressed in terms of physical quality and microbial quality. Physical evaluation is easy but tough in nature. One must be highly trained to identify the changes in the nature of the raw materials/ feeds. This primarily involves parameters such as such as bulk density, colour, odour, hardness (force at rupture), durability, pellet size and water stability. Handling practices followed presently for fish processing waste are not adequate and hence may harbour a number of microbial hazards including lethal toxins and metabolites. *Salmonella* is a major bacterial hazard in animal feed. *E. coli* also has been detected in animal feeds. Similarly, the contamination of foods and animal feeds with mycotoxins is a worldwide problem. Mycotoxins are fungal secondary metabolites that have been associated with severe toxic effects to vertebrates produced by many important phytopathogenic and food spoilage fungi including *Aspergillus*, *Penicillium*, *Fusarium*, and *Alternaria* species.

Environmental impacts

The utilization of fish waste derived feed for feeding livestock may clearly create a further range of potential environmental impacts, if proper measures are not taken. In the case of aquaculture feeds, leaching of protein and other nutrients into the pond can result in deterioration of water, if poor quality feed is used. Similarly, trash fish shreds may have greater loss rate (about 40%). Also, the feed residue deposited on the seabed or pond bottom will cause pollution, resulting in a heightened risk of anoxia and mortality rate.

22. Fish as health food

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As far as India is concerned, the successful outcome of green revolution has answered the challenges of food security due to rapid growth in population. But considering the fact that 35% of Indian population falls still below the poverty line emphasizes the need to recognize fisheries as an important sector of the National economy for meeting the food and nutritional security. In the days ahead, "blue revolution" will be the buzzword to meet the challenges of food and nutritional security.

Fish and fishery products form an important food component for a large section of world population. They represent 15.6% of animal protein supply and 5.6% of total protein supply on a worldwide basis. Fish is the primary source of animal protein for over one billion people of developing countries. It is estimated that 60% of people in developing countries obtain 40-100% of the animal protein in their diets from fish [Lowe *et al*., 1998). Protein.lipids and bioactive compounds from seafood's have unique features that differ from those of land animals. The uniqueness of fish protein is due to its excellent nutritive value, high digestibility and presence of all essential amino acids. In general, fish flesh contains 60-84% water, 15-24% protein, 0.1-22% fat and 1-2% minerals. Seafood serves as a rich source of polyunsaturated fatty acids [PUFAs], especially omega-3 PUFAs, minerals and vitamins [Fierens and Corthout *et al*., 2007].

Fish is a health food, with relatively lesser taboos connected to it, unlike meat. World over fish is considered as a delicious item and in nutritional point of view, it is the balanced diet one can easily think of, when consumed along with cereals. A health food should contain all the principal constituents like carbohydrates, proteins, lipids, minerals, vitamins etc. in the right proportion. Detailed biochemical composition of all important Indian food fishes including proximate composition, fatty acid composition of body and liver oils, content of all important minerals, amino acid composition of muscle proteins etc from fresh water, brackish water and marine and deep sea waters have been compiled and reported by the Central Institute of Fisheries Technology (Gopakumar *et al* ., 1997). People are now more health conscious. Diets low in fat and cholesterol with high vitamin and mineral contents are often preferred, especially in the affluent west. For a healthy lifestyle, fish is a good starting point. Importance of fish as a source of high quality, balanced and easily digestible protein is now well understood. For the affluent it is the best health food with curative properties whereas for the less privileged section in developing nations it is the only source of high-quality protein available at affordable cost and in sufficient quantity.

Fish 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. Meat products are viewed as unsafe after the incidences of diseases like mad cow disease. Fish

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is a versatile, tasty and easy to prepare food. Consumers are increasingly demanding for natural food stuffs, which contain no chemical residues and are not genetically manipulated. Fish is organic and is considered as wild, and for the same reason safer, though of late farmed fish has posed minor problems of harmful residues. For thousands of years, fish has been an important part of the human diet. The ancient Assyrians, Romans and Chinese were famous for their fish farming. During the past decades per capita consumption of fish has gone up globally. Fish is the diet of the poor fishermen, which meets most of their nutritional requirements.

Researchers all over the world have repeatedly emphasized the beneficial effect of eating fish, after conducting systematic research for many years. In recent years, the link between fish oil and heart disease has been the subject of thousands of scientific papers. The whole story began following the discovery that coronary heart disease, while being one of the biggest killers in the world, is practically unknown among the Eskimos. The investigations found that their diet is mostly fish based and is rich in long chain n –3 poly unsaturated fatty acids (Lee and Lip 2003; Von Sehachy and Dyerberg,2001). Eskimos also have a reduced tendency to blood clotting and longer bleeding times compared to other people (Krishnan, *et al.*. 2001). Medical researchers carried out detailed investigations and showed that men who ate fish once or twice per week were protected against coronary heart disease (Ite *et al.* 2004: Eokkila *et al.* 2004). An increase in fish oils in the diet results in a marked reduction in blood cholesterol and triglyceride levels and also thrombosis problem (Bjerregaard *et al*., 2004).

Lipid content in fish varies between species as also within the species depending on many factors. Fish with fat content as low as 0.5% and as high as 18-20% are common (Table 1). Squalene and wax esters are other components found in unusually high concentrations in certain fish. The fatty acid composition of marine lipids is much more complex than others. Lipids of fish and other aquatic animals contain high proportion of highly unsaturated long chain fatty acids. Fatty acids with carbon chain varying from 10 to 22 and unsaturation varying from 0–6 double bonds are common. Among the saturated acids palmitic and stearic acids are the important ones and in the monounsaturated group, palmitoleic and oleic acids are the major constituents. Among the polyunsaturated acids arachidonic acid, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are the major components. In Central Institute of Fisheries Technology, marine, fresh water and brackish water fishes were screened for evaluating their fatty acid composition and in the flesh (Table 4 a-d). Fish and shellfish from tropical waters were analysed for their cholesterol content, showing higher levels in shellfish compared to fish (Mathew *et al*., 1998).

Fish oils have no effect on the levels of low-density lipoprotein cholesterol (LDL); but they do raise high-density lipoprotein (HDL) by about 10%. HDL is a protective type of lipoprotein since it takes excess cholesterol away from the tissue and returns it to the liver. Diseased heart muscle is susceptible to bouts of irregular electrical activity (arrhythmias), which are potentially lethal and often cause sudden cardiac arrests. There is evidence from animal studies that increasing fish oil in the diet helps to reduce cardiac arrhythmias (Sellmayer *et al.*. 2004; Covington 2004). Fish oils improve the functionality of cell membranes, which helps in proper signal transmission. Fish oil inhibits platelet aggregation, which also reduces the risk of heart disease (Vanschoonbeek *et al.*. 2004). Raised blood pressure is known to be a major risk factor in coronary heart disease. Most studies on the effects of fish oil given as dietary supplements have shown modest reductions in blood pressure, especially in hypertensed people (Aguilera *et al.* 2004; Wilbuurn *et al.*. 2004; Maano *et al.*. 1995).

As stated earlier, fish oils are rich sources of the essential fatty acids eicosapentaenoic acid (EPA,C20:5 n-3) and docosahexaenoic acid (DHA, C22:6 n-3). Both EPA and DHA fall into a larger category of polyunsaturated fatty acids (PUFAs). Approximately 50% of the fatty acids in lean fish and 25% in fattier fish are polyunsaturated fatty acids. In contrast, the polyunsaturated and saturated fatty acids in beef are 4 – 10 % and 40 – 45 % respectively. EPA and DHA reduce vasoconstriction by competing with arachidonic acid for the enzyme cyclo-oxygenase (Sametz *et al.* 2000). EPA, the main n-3 acid is converted by platelet cyclo-oxygenase to thromboxane A3, which is only a very weak vasoconstrictor, unlike thromboxane A2, which is formed by the action of cyclooxygenase on arachidonic acid, the n-6 acid and is a strong vasoconstrictor (Tapiero *et al.* 2002; Akiba *et al.* 2000). The American Heart Association recommends including fatty fish at least twice a week in the diet (Kris-Etherton *et al.* 2002; Krauss *et al.* 2000). Institute of Human Nutrition in New York also recommends eating plenty of fish. Italian study involving 985 people who survived heart attacks, also proved the beneficial effect of fish oil (Tavani *et al.* 2001). The new slogan in the west is that a tuna sandwich a day keeps heart problems at bay (Mozaffarian *et al.* 2004; O'Neill 2002). It is also stated that if a person wants to reduce the risk of heart attack by more than 20% he has to eat a tuna sandwich just once a month. No wonder they say, "Seafood is heartfood".

Recently the inhibitory role of n-3 PUFAs in the development and progression of a range of human cancers have been established by researchers, world over. Studies have found that the anti-tumor effect of EPA is mainly related to its suppression of cell proliferation (Pham and Ziboh 2002; Yuri *et al.* 2003). The effect of DHA appears to be related to its ability to induce apoptosis or cell death (Baumgartner *et al.* 2004; Chiu *et al.* 2004). The dietary n-3/n-6 fatty acid ratio, rather than the quantity administered, appears to be the principal factor in the anti-tumor effect of n-3 PUFAs.

Apart from heart disease and cancer, fish oil is proved to be effective for preventing wide variety of diseases. In several observational studies, low concentrations of n-3 PUFAs were predictive of impulsive behaviours and severe mental depression (Ruxton 2004; Freeman *et al.* 2004). The importance of PUFAs in the maintenance of insulin in the blood has also been proved in experiments (Holness *et al.* 2004). Clinical and biochemical studies have shown that fish oil, and to a lesser extent fish can be used as a source of n-3 fattyacids in the treatment of rheumatoid arthritis (Ruxton 2004; Remans *et al.* 2004). Supplementations with fish oils can markedly reduce inter leukin – 1 beta production and results in a significant reduction in morning stiffness and the number of painful joints in arthritis patients. Studies have shown fish oil to be effective in the treatment of acute respiratory distress syndrome (Pacht *et al.* 2003), psoriasis (Mayser *et al.* 2002), and multiple sclerosis (Nordvik *et al.* 200) also. Older people who eat fish at least once a week may reduce their risk of Alzheimer's disease by more than half (Yazawa 2004; Morris *et al.* 2002). Other diseases which are reduced due to the consumption of PUFAs include primary Raynaud's disease (DiGiacomo 1989; Swanson 1986), gastric ulcer (Olafsson *et al.* 2000; Manjari and Das 2000) and Crohn's disease (Geerling *et al.* 2000).

Along with fish oils, proteins in fish are also having positive role in reducing blood cholesterol (Ait Yahia *et al.*, 2004). Recent studies have shown that fish proteins have a clear protective effect in diabetic renal diseases (Mollsten *et al.*, 2001). Fish proteins are having high biological value, as they contain all essential amino acids in the right proportion. Plant proteins, although rich in certain essential amino acids do not always offer all essential amino acids in a single given food. Legumes lack methionine, while grains lack lysine. Fish protein is also an excellent source of lysine as well as the sulphur-containing amino acids, methionine and cysteine. Amino acid scores of fish protein compare well with the FAO reference pattern. In the studies conducted in the Central Institute of Fisheries Technology, Kochi, it was seen that the amino acid composition of the protein is crucial in determining its hypocholesterolemic properties. The alanine/proline ratio in a protein was found to be the significant factor determining its hypocholesterolemic properties (Ammu,K., *et al*.,1994).

Protein content of fish muscle ranges between 16 and 20% depending on the species of the animal, the nutritional condition, and the type of muscle. The crude protein calculated on the basis of the total nitrogen content represents proteins and other nitrogenous compounds, such as nucleic acids, nucleotides, trimethylamine (TMA) and trimethylamine oxide (TMAO), free amino acids, urea, etc**.** Protein from fish is easily digested, with most species showing a protein digestibility greater than 90%. The chemical score or amino acid score compares a food's amino acid pattern to that of whole egg protein. The chemical score of finfish is 70, an indication of its high quality, beef is 69 and cow's milk is 60. The protein efficiency ratio (PER) another measure of protein quality of fish is around 3.5, which is much higher than beef (2.30) and milk proteins (2.5) and close to that of egg (3.92). Fish is a good dietary source of taurine, a non-protein amino acid with multiple functions like neurotransmission in the brain, stabilization of cell membranes and in the transport of ions such as sodium, potassium, calcium and magnesium (Franconi *et al.*, 2004; Birdsall, 1998 ; Del Olmo *et al.*, 2000). Nutritional quality of protein is generally determined by factors like essential amino acid composition, digestibility and biological value. Fish protein is rated high in all the above qualities and is considered as a good dietary protein in all respects (Table1, 2 and 3).

In general, both water soluble and fat-soluble vitamins are present in fish. Fat soluble vitamins A, D, K and E are present in fish in varying amounts-often in higher concentrations than in land animals. The amount of vitamins and minerals is species-specific and can vary with season. The flesh of lean white fish, such as cod, haddock, and pollock, contains from 25 to 50 IU of vitamin A per 100 g, while in the fatty species such as herring, there is from 100 to about 4500 IU of this vitamin in 100 g of meat. The content of vitamin D in sardines and pilchards and in tuna is in the range of 530 to 5400 and 700 to 2000 IU per 100 g, respectively. The contents of vitamin E in the edible parts of fish and marine invertebrates range from about 0.2 to 270 mg/100 g. Fish is a good source of B vitamins. The red meat has higher content of vitamin B than white meat. Fish liver, eggs, milt and skin are good sources of Thiamine (B_1), riboflavin (B_2), pyridoxine (B_6), folic acid, biotin, and Cyanocobalamine (B_{12}).

Fish also contributes appreciable amounts of dietary calcium, iron and zinc. Fish contains copper and those who relish fish bones get a fair share of calcium and phosphorous. Salt-water fish are rich in iodine. The iodine in marine fish ranges from 300-3000 µg/kg. Fish is a good source of almost all the minerals present in seawater (Nair and Mathew, 2000). The total content of minerals in the raw flesh of fish and aquatic invertebrates is in the range of 0.6 to 1.5% of wet weight. Certain seafoods such as snails and tuna are good source of the macro mineral magnesium. Seafood, especially tuna, is an important source of the essential antioxidant trace element selenium, which provides protection against heavy metal poisonings and a variety of carcinogens. Functioning cooperatively with vitamin E, selenium is also a vital factor in protection of lipids from oxidation as part of the enzyme glutathione peroxidase, which detoxifies products of rancid fat. The carbohydrate content of finfish is insignificant, but certain shellfish store some of their energy reserves as glycogen, which contributes to the characteristic sweet taste of these products.

When we consider the beneficial effects of dietary fish, vegetarianism in dietary habits does not seem to be wise. When one decides to become an obligate vegetarian and cuts out meat/dairy/fish out of diet, he decides to cut out some of the major nutrients body needs on a daily basis for effective functioning. The argument that fish lives in unhygienic habitat and polluted waters is also not valid as pollution is a universal phenomenon, affecting air, land and water Fish is the heart food which gives you both satisfaction and health.

Table 1: Principal constituents of fish and beef muscle (in percentage)

Constituent	Fish fillet			Beef muscle
	Minimum	Normal variation	Maximum	
Protein	6	16-21	28	20
Lipid	0.1	0.2-25	67	3
Carbohydrates		<0.5		1
Ash	0.4	1.2-1.5	10.5	1
Water	28	66-81	96	75

Table 2: Essential amino-acids (percentage) in various proteins

Amino-acid	**Fish**	**Milk**	**Beef**	**Eggs**
Lysine	8.8	8.1	9.3	6.8
Tryptophan	1	1.6	1.1	1.9
Histidine	2	2.6	3.8	2.2

Phenylalanine	3.9	5.3	4.5	5.4
Leucine	8.4	10.2	8.2	8.4
Isoleucine	6	7.2	5.2	7.1
Threonine	4.6	4.4	4.2	5.5
Methionine-cystine	0	4.3	2.9	3.3
Valine	6	7.6	5	8.1

Table 3 – Mineral contents of the muscle of some important speciesv

Table 1 and 2. Source: Lahsen Ababouch, 2000 Fish Utilization and Marketing Service
http://www.oceansatlas.com/world_fisheries_and_aquaculture/html/util/compos/compos/proteins.htm

Name of fish	Na	K	Ca	Fe	P
Fresh water fish	**(mg /100g)**				
Calbasu (*Labeo calbasu)*	103.2	310.1	318.5	0.9	395.0
Catla (*Catla catla)*	58.0	161.7	495.2	1.0	245.0
Mrigal (*Cirrhinus mrigala)*	69.5	170.5	352.1	1.1	283.2
Murrel *(Channa striatus*)	45.5	270.2	46.8	2.5	139.5
Mussullah Mahser (*Tor mussullah*)	49.4	250.2	97.2	3.8	78.5
Rohu *(Labeo rohita*)	112.2	132.2	86.3	1.4	128.7
Tilapia *(Oreochromis mossambica)*	-	-	585.2	1.5	235.0
Freshwater shark (*Wallago attu*)	130.0	169.3	160.0	0.6	4.9
Brackish water fish					
Grey mullet (*Mugil cephalus*)	136.4	252.8	136.9	4.4	175.0
Milk fish (*Chanos chanos*)	83.5	251.4	9.3	1.3	179.5
Mullet (*Mugil parsia*)	116.2	204.1	31.6	1.3	168.2
Pearl spot (*Etroplus suratensis*)	126.9	296.7	315.3	1.8	251.0
Marine fish					
Mackerel (*Rastrelliger kanagurta*)	100.2	424.5	42.9	4.6	308.0
Oil sardine (*Sardinella longiceps)*	88.1	196.2	68.3	1.2	118.1
Ribbon fish (*Trichiurus savala*)	-	-	214.7	13.9	225.1

Seer fish (*Scomberomorus guttatus*)	100.2	228.6	72.2	1.1	178.2
Shark *(Scoliodon spp.*)	150.3	263.5	70.4	1.3	148.2
Silver belly (*Leognathus splendens)*	-	-	720.1	2.2	735.2
Tuna (*Euthynnus affinis*)	156.8	1290.3	590.0	10.1	349.0
Caranx (*Caranx spp.)*	112.0	180.6	35.0	6.6	158.2
White bait *(Anchoviella spp.)*	-	-	679.0	3.5	475.0
Ray (*Himantura sp*.)	115.2	271.0	63.0	1.2	162.2
Jew fish *(Daysciena albida*)	68.7	146.4	68.3	2.1	78.3
Bombay duck *(Harpodon nehereus*)	-	-	1390.0	19.0	35.0
Shell fish					
Indian White Prawn *(Penaeus indicus*)	209.0	382.0	32.3	5.3	68.0
Freshwater prawn (*Macrobrachium rosenbergiiI*	182.2	298.6	74.0	1.2	79.9
Mussel (*Perna viridis*)	180.1	251.0	64.3	0.9	2.4
Cuttle fish *(Sepia spp)*	146.3	2.6.0	70.1	7.4	88.3
Sand Lobster (*Thenus orientalis*)	726.2	452.0	488.0	8.1	-

Source : Biochemical composition of Indian food fishes. CIFT, 1997

Fatty acid	Silver jewfish (*Johnius argenteus*)	Caranx (*Caranx kalla*)	Sole (*Cynoglossus semi-fasciatus*)	Seer-white meat (*Scomberomorus guttatus*)	Seer-black meat (*Scomberomorus guttatus*)	Tuna white (*Euthynnus affinis*)	Mullet (*Liza corsula*)	Malabar grouper (*Epinephelus spp.*)	Ribbon fish (*Trichiurus savala*)	Knobby headed flatfish (*Suggrundus tuberculatus*)	Job fish (*Aphareus rutilans*)	Golden anchovy (*Coilia dussumieri*)	Barracuda (*Sphyraena tudes*)	Ray (*Rhinobatus djiddensis*)	Bombay duck (*Harpodon nehereus*)	Horse mackerel (*Megalaspis cordyla*)	Manta ray (*Mobula diabolus*)	Bullseye (*Priacanthus sp.*)
Saturated																		
C12:0	1.0	2.0	0.0	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	-	-	0.1	-	0.4	-	2.5
C13:0	0.7	0.6	0.0	0.1	0.0	0.1	0.2	0.9	0.5	1.8	2.3	-	-	0.3	-	-	-	0.9
C14:0	3.2	8.7	9.6	10.4	11.3	2.0	6.9	2.6	4.9	6.4	4.0	4.7	2.2	1.1	2.8	3.1	1.5	7.7
C15:0	1.6	1.1	1.6	1.5	1.0	1.4	1.1	0.0	1.2	2.2	0.3	0.7	-	0.5	0.3	0.6	0.5	0.8
C16:0	20.7	33.8	32.3	26.0	28.0	30.5	28.3	18.0	19.5	22.8	23.7	33.7	22.2	18.6	20.0	26.9	30.2	24.7
C17:0	0.0	1.7	2.8	3.1	2.0	2.1	1.3	1.1	2.0	2.0	1.5	0.8	1.4	1.0	1.1	0.6	0.8	0.4
C18:0	13.6	15.1	14.0	9.3	9.8	16.6	8.5	13.6	12.8	11.9	4.6	7.5	6.8	3.5	6.1	13.6	-	6.5
C19:0	1.7	0.0	0.0	0.0	0.0	0.0	2.9	0.2	0.0	0.6	0.6	1.1	0.7	0.3	-	0.3	0.5	-
Total	42.5	63.0	60.3	50.7	52.1	52.8	49.2	36.4	40.9	47.7	37.0	48.5	33.3	25.5	30.2	45.4	33.4	43.5
Monounsaturated																		
C16:1 n7	12.1	5.7	9.0	11.2	10.7	2.5	10.6	2.0	4.2	2.8	1.9	8.1	-	3.9	6.0	4.5	5.6	8.8
C18:1 n9	12.2	15.5	19.0	15.0	13.6	24.0	8.7	16.6	18.0	15.6	16.3	14.7	12.7	19.5	14.1	12.3	33.5	15.3
C20:1 n9	1.4	0.4	0.0	2.0	1.0	0.9	1.5	9.0	4.6	3.5	0.0	1.0	-	0.7	-	2.2	0.8	0.5
C22:1 n9	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.9	3.0	-	-	1.5	-	1.0	-	-
Others	0.2	1.3	1.3	2.5	2.3	1.9	11.3	1.1	1.6	7.9	1.6							
Total	25.9	22.9	29.3	30.7	27.6	29.3	32.4	28.7	28.4	30.7	22.8	23.8	12.7	25.6	20.0	19.9	39.9	24.6
Polyunsaturated																		
C18:2 n6	2.8	1.4	1.5	2.4	3.6	0.6	0.0	0.6	2.7	3.5	2.9	1.1	-	2.7	1.7	1.0	4.1	-
C18:3 n3	3.3	0.7	0.7	1.5	1.6	0.2	1.6	2.0	1.5	0.7	3.7	-	-	-	0.2	0.7	-	-
C18:4 n3	0.0	1.5	4.7	0.9	0.7	0.7	2.0	1.5	2.2	0.7	0.7	-	-	-	0.6	-	-	-
C20:2 n6	1.3	0.0	0.0	0.4	0.0	0.0	1.0	0.0	0.0	0.0	0.0	-	-	-	1.6	0.4	-	-
C20:4 n6	6.6	0.2	0.0	0.3	0.2	0.9	0.0	1.8	1.0	2.3	1.8	4.3	8.9	6.9	8.1	4.1	6.4	3.7
C20:5 n6	4.0	5.0	1.5	3.5	3.2	10.2	3.0	3.2	5.7	2.9	4.2	6.0	2.7	2.1	11.2	5.1	1.2	4.8
C22:3 n3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	2.6	1.2	0.0	0.0	-	1.3	-	0.2	-	-	-
C22:4 n6	1.9	0.0	0.0	0.0	0.0	1.1	0.3	4.9	1.7	0.9	1.0							
C22:5 n3	2.3	0.9	0.1	0.5	0.1	1.1	1.0	1.6	1.9	0.9	11.0	1.5	-	2.3	-	1.9	2.5	0.7
C22:6 n3	7.6	4.0	2.0	8.2	10.5	3.2	9.5	16.0	12.5	8.7	14.0	14.0	38.8	13.0	23.1	17.2	6.8	18.8
Others	0.6	0.0	0.0	0.4	0.0	0.0	0.0	0.8	0.3	0.3	0.9	0.8	2.4	21.8	3.1	4.3	5.7	3.4
Total	31.8	13.7	10.5	18.1	19.9	18.0	18.4	35.0	30.7	20.9	40.2	26.9	51.6	27.0	46.7	30.4	21.0	27.9

Table 4 b- Fatty Acid Composition (Marine Species Contd..)

Fatty acid	Gizzard shad (*Anodontosoma chacunda*)	Pomfret white (*Stromateus chinensis*)	Madura anchovy (*Thrissocles kammalensis*)	Oil sardine (*Sardinella longiceps*)	One spotted golden snapper (*Lutjanus fulvilamma*)	Progfish (*Batrichthys grunniens*)
Saturated						
C12:0	0.0	0.0	0.0	0.0	-	-
C13:0	0.0	0.0	0.0	0.0	-	-
C14:0	10.0	8.1	8.0	8.1	2.7	2.1
C15:0	0.8	1.0	1.2	0.3	3.6	2.9
C16:0	31.5	20.8	28.8	27.0	18.3	26.2
C17:0	0.8	1.0	0.9	1.0	4.0	4.9
C18:0	17.6	14.1	9.4	3.8	13.3	11.8
C19:0	0.6	1.0	0.6	0.0	0.0	1.7
Others	-	-	-	-	0.1	1.3
Total	61.3	46.0	48.9	40.2	42.0	50.9
Monounsaturated						
C16:1 n7	3.0	1.5	5.3	6.8	6.8	6.7
C17:1 n7	-			-	5.9	3.2
C18:1 n9	7.5	13.5	4.0	15.4	15.3	16.7
C20:1 n9	0.6	4.0	4.0	2.3	0.9	1.0
C22:1 n9	5.5	1.0	1.8	2.9	0.0	0.0
Others	0.6	1.0	1.8	0.8	4.0	0.0
Total	17.2	21.0	16.9	28.2	32.9	27.6
Polyunsaturated						
C18:2 n6	2.6	3.9	3.5	4.3	5.4	2.7

C18:3 n3	0.7	2.5	2.2	0.8	0.0	1.7
C18:4 n3	0.6	4.0	2.0	1.7	2.8	1.1
C20:2 n6	0.7	0.0	0.0	0.0	0.4	0.0
C20:3 n6	-	-	-	-	0.5	0.2
C20:4 n6	4.3	1.0	1.0	2.6	8.1	4.5
C20:5 n3	4.9	8.0	11.8	10.6	1.2	2.4
C22:2 n6	-	-	-	-	0.1	0.3
C22:3 n6	0.7	0.7	0.3	0.0	0.8	1.8
C22:4 n3	0.7	0.9	0.3	1.2	1.2	0.8
C22:5 n3	3.5	1.6	0.3	0.8	1.7	1.7
C22:6 n3	1.9	8.5	12.0	8.8	3.0	4.0
Others	0.9	1.9	0.8	0.8	-	-
Total	21.5	33.0	34.2	31.6	25.2	21.2

Source : Biochemical composition of Indian food fishes. CIFT, 1997

Table 4 c- Fatty Acid Composition (Marine Species Contd..)

Fatty acid	Oil sardine (*Sardinella longiceps*)	Indian scad (*Decapterus russelli*)	Tiger toothed croaker (*Otolithes ruber*)	Shrimp scad (*Alepes djedaba*)	Four finger threadfin (*Eleutheronema tetradactylum*)	Anchovy (*Engraulis tri*)	Little tuna (*Euthynnus affinis*)	Needlefish *Hemiramphus lutkei*	Splendid pony fish (*Leiognathus splendens*)	Horse mackerel (*Megalaspis cordyla*)	Great barracuda (*Sphyraena barracuda*)	Hammer head shark (*Zygaena tudes*)	Dorab wolf herring (*Chirocentrus dorab*)	Tongue sole (*Cynoglossus semifasciatus*)	Silver biddy (*Gerres filamentosus*)	Whitefish (*Lactarius lactarius*)	Humpback red snapper (*Lutjanus gibbus*)	Japanese threadfin bream (*Nemipterus japonicus*)	Indian flathead (*Platycephalus indicus*)	Silver whiting (*Sillago sihama*)	Six barred reef cod (*Epinephelus diacanthus*)	Greasy reef cod (*Epinephelus tauvina*)	Emperor bream (*Letrinnus cinereus*)
Saturated																							
C10:0	0.2	0.3	-	-	-	-	-	-	-	0.9	2.8										0.4	0.2	0.4
C12:0	0.1	0.1	0.3	-	0.3	0.1	-	2.5	-	0.5	0.6	0.1	-	2.5	-	0.1	0.2	-	-	-	0.2	0.1	0.2
C14:0	9.1	2.4	3.7	2.8	1.9	4.2	0.6	1.2	3.0	2.0	3.6	0.5	4.3	5.5	3.7	2.6	4.5	3.3	1.2	3.1	2.4	3.0	3.3
C15:0	0.6	0.7	1.1	1.1	0.4	0.9	0.3	0.9	2.1	0.8	0.6	0.2	0.7	-	0.8	0.4	0.5	0.7	1.5	0.6	0.7	0.6	0.8
C16:0	23.5	16.3	26.7	21.4	24.5	25.0	15.4	19.6	25.4	16.7	18.4	19.8	30.3	27.8	22.8	30.4	26.3	21.5	27.2	27.0	17.3	22.6	19.7
C17:0	1.8	2.2	2.0	0.6	0.6	2.1	2.0	-	1.2	2.2	1.6	0.4	2.2	1.4	2.1	1.5	0.5	1.9	4.2	0.4	2.4	2.0	2.2
C18:0	5.6	9.2	10.1	11.9	14.8	9.1	11.5	7.8	9.2	11.5	7.7	9.3	7.6	7.5	8.9	8.8	12.0	8.5	10.4	10.1	7.8	14.2	8.0
C19:0	0.8	-	-	0.3	0.5	1.9	0.5	1.3	0.7	0.9	0.7	-	-	0.5	0.8	0.3	0.6	0.8	0.5	-	0.7	0.9	0.8
C20:0	1.1	0.5	-	-	-	-	0.2	-	-	0.5	0.5	0.1	-	2.0	0.6	0.4	-	0.4	-	2.6	0.6	0.6	0.7
Total	42.9	31.8	43.8	38.1	43.0	43.3	30.4	33.3	41.6	35.9	36.4	30.3	45.0	47.2	39.6	44.3	44.6	37.1	45.1	43.8	32.3	44.1	36.0
Monounsaturated																							
C16:1 n7	11.8	4.6	9.3	3.1	2.9	5.7	1.6	1.5	5.6	3.6	5.4	7.1	7.5	6.5	8.0	6.4	7.6	7.2	3.2	7.3	6.1	4.5	5.2
C18:1 n9	8.1	10.8	19.3	7.7	7.5	10.7	7.0	8.8	10.2	8.3	11.1	23.2	10.8	11.7	14.9	25.7	13.8	16.3	13.8	13.4	13.1	9.8	11.9
C20:1 n9	0.8	1.0	0.2	1.6	1.1	-	0.2	1.9	1.7	0.5	1.0	1.6	0.1	1.2	2.7	0.5	1.8	2.2	0.3	1.1	1.7	1.2	1.5
Total	20.7	16.5	28.8	12.4	11.5	16.4	8.8	12.2	17.5	12.4	17.5	31.9	18.5	19.4	25.6	32.6	23.2	25.7	17.2	21.8	20.9	15.5	18.6
Polyunsaturated																							
C18:2 n6	1.3	1.6	3.0	1.8	0.9	1.1	1.2	1.3	1.7	1.1	1.0	-	1.0	1.2	1.6	0.4	1.8	1.3	1.2	0.6	1.2	0.9	1.1
C18:3 n3	-	0.9	0.9	1.1	-	0.7	0.5	-	0.6	0.9	0.8	0.5	0.4	1.8	1.7	0.4	0.8	0.9	-	0.3	0.8	0.6	0.8
C20:2 n6	0.2	0.5	-	0.5	0.2	-	0.3	-	-	0.4	0.3	0.9	-	0.4	0.8	0.1	0.4	0.7	-	4.5	0.6	0.5	-
C20:4 n6	2.5	3.8	4.0	4.4	7.6	5.7	5.5	3.0	8.1	3.5	3.2	4.1	1.8	4.0	3.7	2.0	3.6	4.6	6.8	3.8	5.5	3.6	4.5
C20:5 n3	11.8	8.1	5.6	5.9	6.8	3.8	7.3	4.1	7.0	0.7	6.6	2.9	5.3	6.0	5.9	3.8	10.8	4.7	3.6	7.5	5.5	4.7	6.8
C22:4 n3	-	2.9	-	-	0.3	-	4.9	0.1	-	3.2	2.0	4.0	-	-	1.7	1.4	-	3.1	-	-	4.4	2.3	3.4
C22:5 n3	-	-	1.4	2.1	2.8	0.7	-	4.7	1.5	-	-	-	0.3	-	-	-	1.1	2.2	1.7	2.4	-	-	-
C22:6 n3	15.5	29.7	8.5	28.5	23.8	25.2	38.1	33.6	15.2	34.0	27.7	20.8	26.4	11.7	14.2	12.9	10.8	15.2	20.1	14.5	24.3	24.6	25.1
Total	31.3	47.5	23.5	44.3	42.4	37.2	57.9	46.8	34.1	43	41.5	33.2	35.0	25.1	29.5	21.0	29.3	32.6	33.4	33.6	42.4	37.1	41.7
Others	5.3	4.2	3.5	5.0	2.8	2.7	2.5	7.3	6.1	8.6	4.0	5.2	1.2	8.7	5.9	2.3	2.5	4.6	3.8	0.6	4.5	3.0	3.7

Source : Biochemical composition of Indian food fishes. CIFT, 1997

Fatty acid	Shark (*Scoliodon sorrokowah*)	Whale shark (*Rhiniodon typus*)	Shark (*Carcharinus*	Hammer head shark (*Zygaena tudes*)	Hilsa (*Hilsa toli*)	Reef cod (*Epinephelus sp.*)	Reef cod (*E. diacanthus*)	Dhoma (*Otolithes argenteus*)
Saturated								
C12:0	-	-	-	-	0.1	0.3	0.5	0.4
C14:0	0.5	1.5	0.7	0.1	9.9	2.0	3.1	2.0
C15:0	2.3	-	0.7	0.2	0.3	0.6	0.7	0.6
C16:0	32.3	29.7	28.7	20.1	28.2	25.9	25.3	40.4
C17:0	0.6	0.2	0.6	0.5	0.5	1.3	0.7	0.4
C18:0	17.2	-	-	12.9	-	8.8	10.3	10.1
C19:0	-	0.2	-	-	1.2	-	-	0.5
Total	52.9	31.6	30.6	33.7	40.2	38.9	40.6	54.0
Monounsaturated								
C16:1 n7	2.0	7.1	4.6	2.9	7.7	1.2	3.7	6.8
C18:1 n9	12.9	46.2	52.5	25.6	21.6	17.0	13.3	12.3
C20:1	2.5	10.4	-	-	1.5	1.0	2.0	0.8
C22:1	-	1.6	-	-	0.3	-	1.0	0.1
Total	17.3	65.2	57.1	28.5	31.1	19.2	19.9	20.0
Polyunsaturated								
C18:2 n6	0.6	0.3	0.5	-	1.2	2.0	0.8	0.9
C18:3 n3	-	-	-	-	0.9	0.7	0.6	0.5
C18:4 n3	-	-	-	0.3	-	-	-	-
C20:2	-	-	-	0.2	-	-	-	-
C20:4 n6	6.7	0.5	6.1	8.2	3.0	5.5	5.6	4.1
C20:5 n3	1.7	0.3	-	2.7	7.0	5.0	3.4	3.7
C22:3 n3	-	-	-	0.7	-	-	-	-
C22:4 n3	-	-	-	-	-	-	-	-
C22:5 n3	7.4	0.8	-	0.9	0.6	3.0	4.1	1.4
C22:6 n3	9.3	1.1	3.1	21.5	12.2	21.4	19.3	12.3
Total	25.6	3.0	9.6	34.5	24.8	37.6	33.9	22.9

Table 4 d - Fatty Acid Composition (Brackish

Fatty acid	Catfish (*Pseudarius spp.*)	Giant catfish (*Netuma*	Grey mullet (*Mugil cephalus*)	Pearlspot (*Etroplus suratensis*)	Milkfish (*Chanos chanos*)
Saturated					
C14:0	4.4	6.9	3.9	1.8	2.9
C15:0	2.2	3.9	5.8	0.7	0.8
C16:0	16.4	22.0	20.3	21.2	22.3
C17:0	5.0	4.3	5.9	0.0	0.0
C18:0	18.4	13.3	5.2	11.7	7.6
C19:0	1.6	1.1	1.7	0.0	0.0
Others	0.2	0.5	0.3	0.6	0.8
Total	48.2	52.0	43.1	36.0	34.4
Monounsaturated					
C16:1 n7	7.6	7.9	10.6	8.0	5.7
C17:1 n7	0.0	1.9	5.7	0.0	0.0
C18:1 n9	18.0	12.3	14.4	22.6	15.0
C20:1 n9	0.5	0.8	5.1	0.0	3.5
C22:1 n9	0.0	0.8	1.1	0.0	1.1
Others	0.0	0.0	0.0	0.0	0.0
Total	26.1	23.7	36.9	30.6	25.3
Polyunsaturated					
C18:2 n6	0.7	3.3	0.0	4.0	3.0
C18:3 n3	5.8	0.0	4.0	5.2	2.2
C18:4 n3	0.5	3.5	0.8	0.0	1.9
C20:2 n6	0.0	1.7	0.0	2.7	0.0
C20:3 n6	0.0	1.6	0.0	2.3	0.0
C20:4 n6	3.3	3.6	2.9	6.0	5.4
C20:5 n3	5.5	4.4	3.3	1.9	4.3
C22:2 n6	0.6	0.0	0.0	0.0	0.0
C22:3 n3	1.5	0.6	0.7	1.4	1.7
C22:4 n3	0.0	2.1	3.1	1.6	2.5
C22:5n3	3.2	2.1	1.8	3.0	5.7
C22:6n3	4.8	1.6	2.8	4.9	15.5

Table 4 e- Fatty Acid Composition (Fresh water species)

Fatty acid	Spiny eel (*Mastacembelus armatus*)	Green snakehead (*Ophicephalus punctatus*)	Filamented barb (*Puntius filamentosus*)	Orange chromicle (*Etroplus maculatus*)	Stinging catfish (*Heteropneustes fossilis*)	Pearlspot (*Etroplus suratensis*)	Milkfish (*Chanos chanos*)	Waigue snapper (*Lutjanus vaigiensis*)	Freshwater shark (*Wallago attu*)
Saturated									
C12:0	2.1	0.0	0.3	0.0	1.2	0.0	0	0	3.4
C13:0	0.7	0.3	2.0	0.2	1.4	1	0	0.2	0.4
C14:0	3.6	0.7	3.4	3.4	3.3	3.8	1.6	2.4	3.2
C15:0	3.0	2.1	1.5	1.1	2.2	2.8	1	1	1.5
C16:0	13.7	24.0	13.4	24.7	17.6	19.9	19.9	17.6	20
C17:0	3.8	3.0	2.3	2.8	2.5	0.4	2.6	2.6	1.4
C18:0	12.6	13.7	16.8	12.0	9.4	15.7	10.4	10.8	9.4
C19:0	1.8	1.3	0.9	0.9	1.6	0	2.5	1.6	0
Total	41.3	45.1	40.6	45.1	39.2	43.6	38	36.2	39.3
Monounsaturated									
C16:1 n7	7.5	5.8	7.9	6.3	16.5	11.1	8.4	7.6	6.9
C17:1 n7	1.1	2.0	1.6	1.2	0.0	0.4	2.4	0	0
C18:1 n9	20.4	14.0	18.6	13.7	15.3	20.3	20.8	32	22.1
C20:1 n9	1.0	0.7	0.0	0.9	0.0	1.6	1.8	0.8	0.6
C22:1 n9	0.5	0.3	1.1	0.7	0.9	1	0	0.9	0.7
Others	3.0	1.8	0.0	0.2	2.5	0.1	1	0.6	3.2
Total	33.5	24.6	29.2	23.0	35.2	34.5	34.4	41.9	33.5
Polyunsaturated									
C18:2 n6	8.2	3.8	10.4	2.1	4.1	7.6	3.5	4.9	6.8
C18:3 n3	1.9	0.5	4.0	0.6	0.9	5.5	3.7	3.6	3.6
C18:4 n3	1.6	1.8	1.2	3.6	1.7	2.4	7	1.6	2.4
C20:2 n6	0.0	0.2	0.6	1.0	1.0	0	0	1.1	1.3
C20:3 n6	1.5	0.2	1.2	0.7	2.1	0	1.2	0.6	0
C20:4 n6	7.1	6.1	6.7	3.0	6.3	3.5	2.4	3.2	4.6
C20:5 n3	1.2	6.0	1.4	2.2	3.8	0.5	2.2	0.9	0.8
C22:4 n6	1.3	2.4	0.8	5.9	0.9	0	1.8	1.4	0
C22:5 n3	0.3	2.2	0.2	5.1	0.5	1	0.5	0.7	0
C22:6 n3	2.2	6.7	2.6	8.0	0.3	1	2.4	1	2.8
Others	0.0	0.0	0.3	0.0	1.3	0.5	2.9	0	3.1
Total	25.3	29.9	29.4	32.2	22.9	22	27.6	19	25.4
Unidentified	-	0.4	0.8	-	2.8	0	0	3	2

Source - *S. Ma/hew et al. Food Chemistry 66 (1999) 455-461*

Table 5 : Content of cholesterol, NSM and fat (a) in fish, (b) in shellfish

S. Mathew et al. Food Chemistry 66 (1999) 455-461

No. family	Species	Common name	Length Weight (average)		Month	Cholesterol	NSM	Fat
			(cm)	(g)		(mg%)	(g%)	(g%)
(a) Fish								
I Acanthuridae	*Acanthurus xanthopterus* (Valenciennes, 1835)	Yellow fin surgeon fish			October	33.8	0.05	0.99
2 Ariidae	*Arius fella* (Day,1877)	Black fin sea catfish	25	300	July	58.3		1.6
3 Ariidae	*.4rius fella* (Day,1877)	Black fin sea catfish	32	315	March	56.9	0.09	0.72
4 Ariommidae	*Ariomma indicus (Day, 1870)*	Indian drift fish				59.9	0.25	2.4
5 Belonidae	*Strongvlura strongylura* (Van Hasselt, 1823)	Spot tail needle fish	35	145	Februray	55	0.07	0.86
6 Bothidae	*Pseudorhombus* sp	Flounder	15	40	March	64.7	0.13	0.3
7 Bothidae	*Pseudorhombus* sp	Flounder	14	29.5	March	51.9	0.11	0.55
8 Carangidae	*Megalaspis cordyla* (Linnaeus, 1758)	Torpedo scad	21	100	Februray	59.1	0.1 1	1.6
9 Carangidae	*Megalaspis cordyla* (Linnaeus, 1758)	Torpedo scad (with skin)	21	100	Februray	62.3	0.15	1.88
10 Carangidae	*Trachynotus ovatus*	Pompano	19	193		55	0.1	1.04
11 Carangidae	*Caranx carangus* (Bloch, 1793)	Black tailed trevally	14	968	October	52.6	0.28	7.11
12 Carangidae	Scomberoides tol	Needle scaled			March	48.1	0.12	1.02

	(Cuvier, 1832)	queen fish						
13	Carangidae *Trachynotus ovatus*	Pompano	20	220	October	47.4	0.08	1.94
14	Carangidae *Megalaspis cordyla* (Linnaeus, 1758)	Torpedo scad	20	120	March	50.9	0.08	0.64
15	Carangidae *Parastromateus niger* (Bloch, 1975)	Black pomfret	23	250	March	60.2	0.1 1	1.09
16	Carangidae *Decapterus russelli* (Ruppell, 1830)	Indian scad	18	49	March	67.6	0.12.	1.34
17	Carangidae *Scomberoides tol* (Cuvier, 1832)	Needle scaled queen fish	36	285	March	55.1	0.09	0.88
18	Carangidae *Megalaspis cordyla* (Linnaeus, 1758)	Torpedo scad	37	424	March	55.1	0.11	1.01
19	Carangidae *Carangoides malabaricus* (Bloch & Schneider, 1801)	Malabar trevelly	16	75	March	55.9	0.16	1.61
20	Carangidae *Carangoides malabaricus* (Bloth & Schneider, 1801)	Malabar trevelly				47.6	0.14	1.16
21	Carangidae *Caranx carangus* (Bloch. 1793)	Black tailed trevally	20	99	March	67.3	0.13	1.01
22	Carangidae *Caranx para* (Cuvier, 1832)	Banded scad	15	32	March	73.7	0.13	1.73
23	Carangidae *Atropus atropus female* (Schneider, 1801)	Cleft belly trevally	23	181	March	64.6	0.15	3.41
24	Carangidae *Atropus atropus* (Schneider, 1801)	Cleft belly trevally	18	91	March	57.1	0.09	1.52
25	Chanidae *Chanos chanos* (Forsskal, 1775)	Milk fish	35	300	December	33.6	0.05	0.98

26 Chirocentrida	*Chirocentrus dorab*	Silver bar			October	39.6	0.06	2.42
27 Chirocentrida	*Chirocentrus nudus* (Swainson, 1839)	White fin wolf herring	49	94.32	March	46	0.2	
28 Chirocentrida	*Chirocentrus nudus* (Swainson, 1839)	Wolf herring	45	364	March	39.4	0.1	1.56
29 Cichlidae	*Oreochromis mossambica*	Tilapia female	16	65	December	41.8	0.06	0.51
30 Cichlidae	*Etroplus maculatus* (Bloch, 1785)	Orange chromicle	7	7.5	December	5.12	0.07	0.71
31 Clupeidae	*Opisthoptertus tardoor* (Cuvier, 1829)	Tardoore	15	30	July	68.6	0.11	4.9
32 Clupeidae	*Opisthoptertus tardoor* (Cuvier, 1829)	Tardoore	16	44	October	62.2	0.36	6.3
33 Clupeidae	*Opisthoptertus tardoor* (Cuvier, 1829)	Tardoore	24	110	March	53.7	0.1 1	1.46
34 Clupeidae	*Dussumieria acuta* (Valenciennes, 1847)	Rainbow sardine	17	41	March	50.4	0.13	0.94
35 Clupeidae	*Sardinella melanura* (Cuvier, 1829)	Blacktip sardinella	16	49	March	52.7	0.09	1.8
36 Clupeidae	*Dussumieria hasse/ti*	Oil sardine	16	25	June	86.5	0.25	4.34
37 Cynoglossida	*Cynoglossus dubius*	Carrot tongue sole	33	213	March	39.2	0.07	0.47
38 Cynoglossida	Cynoglossus sp	Flounder	19	38	March	48.3	0.1	0.24

39 Cyprinidae	*Cirrhinal mrigata* (Hamilton & Buchanan, 1802)	Mrigal				36	0.06	
40 Cyprinidae	*Labeo rohita* (Hamilton and Buchanan, 1802)	Rohu	Adult			36.2	0.07	
41 Elopidae	*Flops machnata* (Forsskal, 1775)	Lady fish	52	900	December	32.9	0.05	0.47
42 Engraulidae	*Tryssa dusumeiri* (Valenciennes, 1848)	Dussumier's thryssa	15	30	Februray	54.6	0.26	3.15
43 Ephippidae	*E phippus Orbis* (Bloch, 1787)	Spade fish	11	42	March	82.7	0.26	3.19
44 Gerridae	*Gerres filamentoses* (Cuvier, 1829)	Whipfin silver biddy	15	84		53.8	0.09	2.35
45 Gerridae	*Gerres filamentoses* (Cuvier, 1829)	Whipfin silver biddy	18	84	October	45.9	0.09	2.2
46 Haemulidae	*Pomadasys furcatum*	Grunter	19	100	February	61	0.22	4.63
47 Haemulidae	*Pomadasys kaakan* (Cuvier, 1830)	Javelin grunter			March	53.7	0.13	0.67
48 Haemulidae	*Pomadasys sp*	Grunter	15	63	March	63.8	0.12	0.93
49 Hemiramphid	*Hemiramphus lutkei*	Needle fish			October	52.5	0.12	1.74
50 Lactaridae	*Lactarius lactarius*	False trevally	14	40	• July	97.4	0.38	6

	(Bloch & Schneider, 1801)							
51 Leiognathidae	Leiognathus equulus (Bloch, 1787)	Pugnose ponyfish			May	90.6	0.15	
52 Leiognathidae	*Leiognathus splendens* (Cuvier, 129)	Splendid ponyfish			May	107	0.14	1.1
53 Leiognathidae	*Leiognathus bindus* (Valenciennes, 1835)	Orange fin pony fish	8	7	March	88.2	0.31	1.85
54 Lethrinidae	*Lethrinus cinerius*		44	1200	October	148	0.37	3.26
55 Lutjanidae	*Lutjanus gibbus* (Forsskal, 1775)	Humpback red snapper	31	850	March	95.5	0.24	7.7
56 Lutjannidae	*Pristipomoides filamentoses* (Valenciennes, 1835)	Blue spotted job fish			October	80.6	0.2	5.03
57 Megalopidae	*Megalops cyprinoides* (Broussonet, 1782)	Oxeye tarpon	18-	69	December	46.2	0.07	0.62
58 Mugilidae	*Vaiamugil cunnesius* (Valenciennes, 1835)	Long arm mullet				62.9	0.25	2.24
59 Mullidae	*Upenus vittatus* (Forsskal, 1775)	Striped goatfish	15	50	March	48.7	0.15	1.01
60 Mullidae	*Upenus vittatus* (Forsskal, 1775)	Goat fish				43.1	0.1	0.89
61 Myliobatidae	*Mydiobatis nieuhofli*	Eagle ray	27	1040	March	56	0.09	0.67

62 Nemipteridae	*Nemipterus bleekeri*	Pink perch	22	119	March	63.4	0.12	0.8
63 Nemipteridae	*Nemipterus japonicus* (Bloch, 1791)	Pink perch	21	130	March	56.4	0.09	0.83
64 Nemipteridae	*Parascolopsis eriomma*	Rosy monacle bream	27	375	February	46.5	0.1	1.56
65 Polynemidae	*Eleutheronema tetradactylus*	Four finger thread fin	33	500	Februray	63.7	0.1	0.85
66 Polynemidae	*Polynemus sextarius* (Bloch and Schneider, 1801)	Blackspot threadfin	15	43	March	68.5	0.11	1.08
67 Priacanthidae	*Priacanthus sp*	Bull eye	18	75	March	53.1	0.1	0.52
68 Psettodidae	*Psettodes erumei* (Schneider, 1801)	Indian tiny turbot	33	587	March	41.6	0.07	0.54
68 Psettodidae	*Psettodes erumei* (Schneider, 1801)	Indian tiny turbot	33	587	March	41.6	0.07	0.54
69 Scianidae	*Nibea maculata* (Schneider, 1801)	Blotched croaker	23	150	January	38.8	0.12	1.56
70 Scianidae	*Johnius carutta* (Bloch, 1793)	Karut croaker	18	65	October	74	0.08	1.2
71 Scianidae	*Johniops Sinai* (Cuvier, 1830)	Sin croaker	14	33	May	69.6	0.1	0.6
72 Scianidae	*Johniops sinai* (Cuvier, 1830)	Sin croaker	12	18	May	72.1	0.23	0.8
73 Scianidae	*Johnius elongates*	Spindle croaker	16	74	March	65.6	0.11	0.87

	(Mohan, 1967)							
74 Scianidae	*Otolithus ruber* (Schneider, 1801)	Tiger toothed croaker	34	458	March	41.7	0.05	0.81
75 Scianidae	*Johniops sina* (Cuvier, 1830)	Sin croaker	17	80	March	59.7	0.1	0.85
76 Scombridae	*Rastrelliger kanagurta* (cuvier, 1817)	Mackerel	12	15	May	51.4	0.05	6.84
77 Scombridae	*Rastrelliger kanagurta*	Mackerel female	27	259	September	58.4	0.18	7.65
78 Scombridae	*Rastrelliger kanagurta*	Mackerel male	23	127	June	55.6	0.17	5.09
79 Scombridae	*Rastrelliger kanagurta*	Mackerel immature	18	70	June	64.8	0.09	2.08
80 Scombridae	*Rastrelliger kanagurta*	Mackerel female	21	115	October	*65.4*	0.14	5.17
81 Scombridae	*Elachata nigra*	Kadal varal	*46*	*750*	October	*59.3*	0.1	1.38
82 Scombridae	*Rastrelliger kanagurta*	Mackerel	*21*	119	March	*69.7*	0.15	1.94
83 Scombridae	*Elachata nigra*	Kadal varal	44	514	March	*65.6*	*0.1*	*0.68*
84 Serranidae	*Epinephles latijasciatus* (Temminck and Schlegel, 1842)	Banded grouper	*27*	*283*	March	41.4	*0.08*	*0.42*
85 Sillaginidae	*Sillago sihama (Forsskal, 1775)*	Silver sillago	14	30	March	*112*	*0.12*	*3.39*
86 Sparidae	*Argyrops spinifer* (Forsskal, 1775)	King soldier bream	20	190	March	*37.8*	*0.06*	0.43
87 Sphyraenidae	*Sphyraena forsteri* (Cuvier, 1829)	Big eye barracuda	30	125	March	*58*	0.1	*0.61*
88 Sphyraenidae	*Sphyraena obtusata (Cuvier, 1829)*	Obtuse barracuda	23	80	March	*59.9*	*0.09*	*0.84*

89 Sphyraenidae	*Sphyraena jello (Cuvier, 1829)*	Barracuda	45	510	March	*34.6*	*0.09*	*0.53*
90 Stromateidae	*Pambus argentius (Epiphrases, 1788)*	Silver pomfret	16	150	March	*44*	*0.1*	*1.08*
91 Synodontidae	*Saurida undosquamosis* (Richardson, 1840)	Brush tooth lizard fish	24	*98*	March	*57.6*	0.11	*1.22*
92 Teraponidae	*Theraponjarbua (Forsskal, 1775)*	Jarbua therapon			October	*33.7*	0.1	*1.94*
93 Teraponidae	*Terapon jarbua*	Jarbua therapon				*24.6*	*0.06*	*0.96*
94 Torpedinida	*Narcine sp*	Electric ray	23	1.1	March	*72.7*	*0.1*	*0.78*
95 Trachinidae	*Percis pulchella*	Rosy grub fish	14	*35*	March	*22.2*	0.04	*0.72*
96 Trichiuridae	*Lepturacanthus savala* (Cuvier, 1917)	Savalai hair tail	47	*87*	March	*68*	0.1	*0.88*
97 Uranoscopide	*Chanoscopes* sp	Star gazers	*28*	*399*	March	*37*	0.11	0.87
Fish Egg								
1 Scombridae	*Rastrelliger kanagurta*	Mackerel egg			September	*462*	1.38	*5.71*
Prawn								
(b) Shellfish								
1 Penaeidae	*Penaeus indicus* (H.Milne Edwards, 1837)	Indian white shrimp	13	*14*	February	*129*	0.17	*1.35*
2 Penaeidae	*Penaeus indicus*	Indian white shrimp	17	*22*	February	163	0.18	1.34
3 Penaeidae	*Metapenaeus monoceros* (Fabricius, 1798)	Speckled shrimp	*7*	*2.75*	February	144	0.18	*0.95*
4 Penaeidae	*Metapenaeus monoceros*	Speckled shrimp	*9*	*6.25*	February	123	0.17	1.22
5 Penaeidae	*Penaeus monodon*	Giant tiger prawn	19	*45*	February	118	*0.25*	1.02

	(Fabricius, 1798)							
6 Penaeidae	*Metapenaeus dobsoni* (Miers, 1878)	Kadal shrimp	9	*3.13*	February	120	*0.23*	1.34
7 Penaeidae	*Metapenaeopsis stridulens* (Alcock, 1905)	Fiddler shrimp	8	*2.3*	March	143	*0.23*	0.98
Crab								
1 Scyllaridae	*Scylla seffata* (Forsskal)	Mud crab	10	180	May	*54.8*	0.15	*0.75*
2 Scyllaridae	*Scvlla serrata* claw meat					51.5	*0.09*	0.64
3 Portunidae	*Portunus sanquinolentus* (Herbst)	Red spot crab	13	*110*	May	52.4	*0.1 1*	0.58
4 Portunidae	*Charibdis cruciata ("Herbst)*	Coral crab	10	*156*	May	56.5	*0.11*	0.7
5 Portunidae	*Charibdis cruciata*	Coral crab	11	*190*	March	54.2	*0.09*	0.76
6 Portunidae	*Portunus pelagicus* (Herbst)	Sand Crab	14	*1 11.*	May	66.8	*0.14*	0.68
Antartic krill								
1 Euphausidae	*Euphausia* sp	Antartic krill	Whole			102	0.13	
2 Euphausidae	*Euphausia sp*	Antartic krill	Tailmeat			33.3		
Cuttle fish								
1 Sepiidae	*Sepia aculeate*	Cuttle fish				162	*0.22*	1.3
2 Sepiidae	*Sepia aculeata*	Cuttle fish	10	67	March	130	0.24	*0.92*
Squid								
1 Loliginidae	*Loligo duvauceli* (Orbingy)	Squid	15	*52*	March	198	*0.34*	1.4

2 Loliginidae	*Loligo duvauceli*	Squid	188	*0.23*	1.33

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23. Profiling of macro and micronutrients in seafood

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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.

1. 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

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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.

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

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

X=Titre value of the sample

V=Total volume of digest

V1=Volume of digest taken for distillation

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

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

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.

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

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 sulphate 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

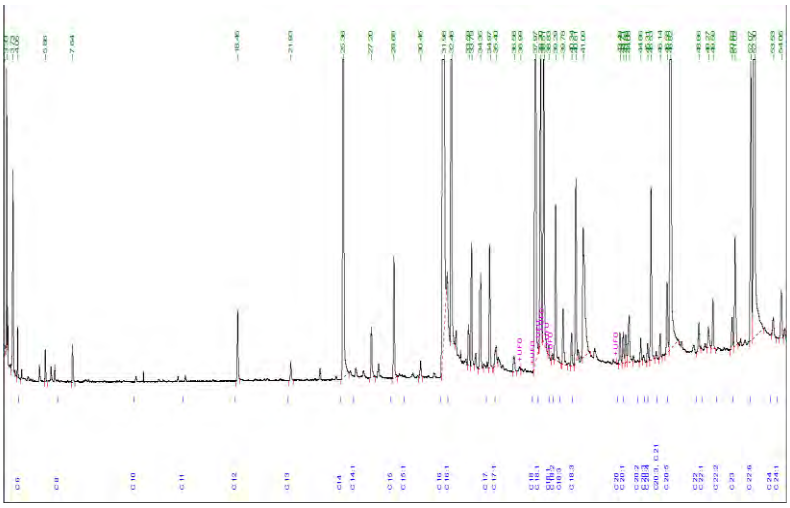

Figure 4: Chromatogram of Fish

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.

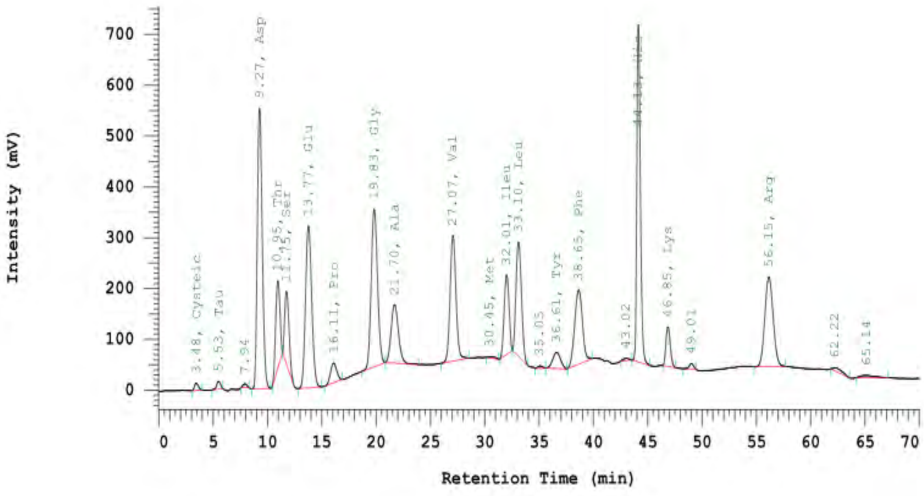

Figure 5: Chromatogram of amino acids

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

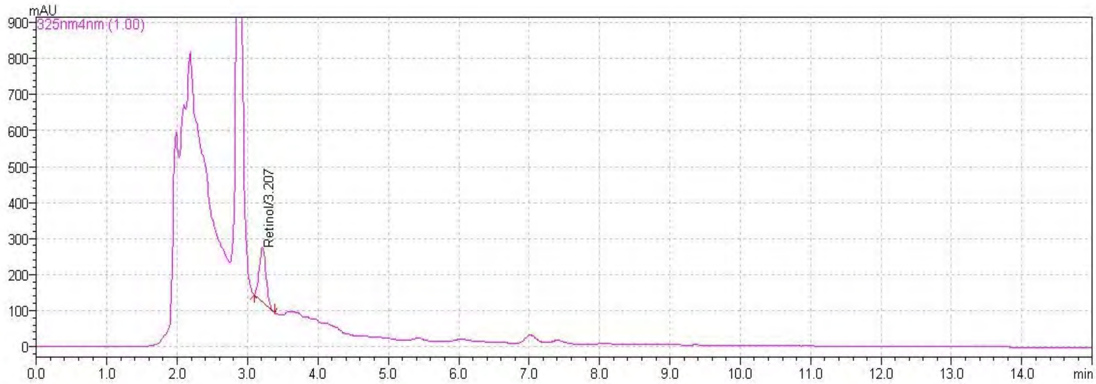

Figure 8: Chromatogram Vitamin A

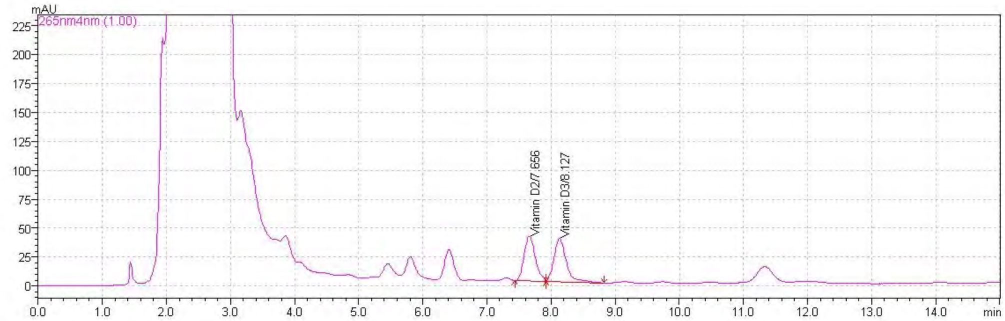

Figure 9: Chromatogram Vitamin D

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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24. Microencapsulation for food fortification

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The United Nations Member States, in 2015 had adopted the 2030 Agenda for Sustainable Development which provides a framework of 17 Sustainable Development Goals for achieving peace and prosperity for people and the planet. All nations recognize that ending poverty should align with strategies that improve health and education, reduce inequality, and stimulate economic growth- and at the same time, tackle climate change and work to preserve our oceans and forests.

Sustainable Development Goal 2 aims to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture by 2030. The triple burden of malnutrition – undernutrition, hidden hunger and overweight – threatens the survival, growth and development of children and young people. Well-nourished children are better able to grow and learn, to participate in their communities and to be resilient in the face of disease, disaster and other emergencies.

According to the WHO, 690 million people (8.9 per cent of the world's population) were hungry in 2019. Children, adolescents and young adults from the poorest and most marginalized communities bear the greatest burden of all forms of malnutrition. Worldwide, nearly half of all deaths in children under 5 are attributable to undernutrition. In 2019, 144 million children under 5, or 21.3 per cent were stunted, 47 million or 6.9 per cent, were wasted (of which 14.3 million were severely wasted) and 38 million, or 5.6 per cent, were overweight. Malnutrition during pregnancy can also affect nutrition outcomes in children, notably one third of females aged 15 to 49 years worldwide were affected by anemia in 2016, with no notable change over the last 2 decades. Central to all of the nutrition-related disorders and disease conditions is hidden hunger or micronutrient (mineral and vitamin) deficiencies. Widespread consumption of poor-quality food leads to hidden hunger, which ravages economies and worsens poverty, according to International Food Policy Research Institute. Globally, more than 2 billion people are micronutrient deficient not because they do not have access to food, but because they fail to receive enough micronutrients from the poor-quality food they eat which makes them sick with various deficiency conditions.

Hunger and consequences.

Hunger in all forms poses a serious challenge to sustainable development as hungry

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people tend to be less productive and are easily prone to diseases. While global progress on curtailing chronic hunger has been seeing considerable improvement, progress on improving hidden hunger has been much slower. Ironically, undernutrition has been on the rise globally since 2015 after showing a significant downward trend for decades. This trend has been essentially due to major setbacks in food production and distribution systems due to climate change; locust infestation in East Africa, Arab Peninsula, the Indian subcontinent and South America; conflicts and war; and the very recent global crisis of the COVID pandemic. These stresses on food systems very easily impact the most poor and susceptible sections of the population, drastically reducing their purchasing power and cutting off their access to food, driving them into an abyss of hunger.

Chronic Hunger and Hidden Hunger

Chronic hunger is a consequence of undernourishment or inadequacy of calories or of one or more nutrients and is also referred to as undernutrition. The four consequences of chronic hunger are: (i) **being underweight** for one's age, defined as *low weight for age* in children and *BMI lower than 18.5* in adults; (ii) **stunting** and **(iii) wasting** in children defined as *being too short for one's age* and *being dangerously thin for one's height* respectively; and (iv) **hidden hunger** or **micronutrient malnutrition**-*being deficient in micronutrients or vitamins and minerals*.

Hidden hunger develops when there is low intake or absorption of vitamins and minerals essential for proper health and physical and mental development in children and normal productive functioning in adults. Particularly susceptible are women and children specifically those from marginalized communities as they have stages of life when there is a surge in physiological need for micronutrients during periods of menstruation, pregnancy and lactation in women and period of spurt in growth in children. Causes include inadequate wholesome diets and frequent occurrence of disease especially in infancy and childhood and enhanced physiological needs that are summarily not met. Children exposed to grave levels of hidden hunger right from the time of conception to infancy and early childhood which is within the crucial window of 1000 days of existence are crippled for life as a consequence of severe physical and cognitive impairments. They are never quite able to resuscitate themselves from the viscous cycle and outcomes of micronutrient deficiency and grow in to adults who underperform in society curtailing the country's socioeconomic development. Undernourished and micronutrient deficient girls become young women who contribute to intergenerational undernutrition by bearing low birthweight children that suffer from both undernutrition and hidden hunger from birth.

Hotspots of hidden hunger

Micronutrients deficiency is a major threat for more than half of the world population living in the developing countries. The two regions considered to be hotspots where prevalence of hidden hunger is the highest are the sub Saharan Africa and South Asia. The most commonly recognized vitamin and mineral deficiencies deemed responsible for hidden hunger in the order of incidence are iodine, iron, zinc, vitamin A, calcium, vitamin D and B vitamins. Of the 3.1 million child deaths that occur globally each year, a whopping 1.1 million are caused by hidden hunger. Iron deficiency is the most common and widespread nutritional disorder in the world and it makes a public health problem in both industrialised and non-industrialised countries. In severe cases, iron deficiency causes anaemia. Anaemia is the outcome of a reduced haemoglobin level in blood causing mental disorders, severe pregnancy problems, and premature delivery. In addition, iron deficiency leads to impaired motor development, anemia, low energy, pregnancy and childbirth-associated morbidities. Worldwide, about 18 million babies are born with brain damage each year due to maternal iodine deficiency. Anemia also causes over 50000 maternal deaths during child birth, in addition to causing preterm births, low birthweight and infant deaths. Iron deficiency has left about 40% of women low on energy in the developing world. In India, over 50% of women are anemic contributing significantly to its burden of disease. Folic acid deficiency causes megaloblastic anaemia, increases the susceptibility to cancer, leads to neural tube defects and vascular diseases.

Most of the vitamin A deficiencies occur in the developing countries and are common in South and South East Asia. Women, being the most susceptible group, are influenced by vitamin A deficiency (VAD) during pregnancy and lactation. VAD affects normal functioning of the visual system, cell function, epithelial cellular integrity, immune function, and reproduction. VAD has affected over two million people, especially pregnant women and young children, in the developing countries. Vitamin A and zinc deficiency in children impair the immune system causing increased susceptibility to disease.

Zinc deficiency reduces growth and leads to stunting in children. Lack of iodine and iron in diet causes cognitive impairment. Zinc interferes with the cell division, protein synthesis, and growth which indicates its need for infants and pregnant and lactating women. Zinc deficiency affects infants, pregnant and lactating women, and also leads to growth retardation and cognitive impairment. The consequences of iodine deficiency include goitre, cretinism, paralysis, and deaf-mutism.

Food fortification has contributed effectively to improving the micronutrient status in adults and children in several countries across the globe. According to WHO, in most regions in the world, bread consumption is high in most countries and flour fortification offers an opportunity to deliver adequate levels of iron. Fortification with micronutrients of staple foods like wheat flour, ubiquitously used condiments like salt is strongly recommended to overcome the related nutrient deficiencies. Micronutrient fortified foods have certain technical limitations which must be considered on the priority basis to make this program successful.

Micronutrients fortification: unencapsulated vs. microencapsulated forms

Whole wheat flour when fortified with ferrous sulphate, zinc sulphate, zinc oxide, the following observations on were made on the flour quality. Due to elemental iron and zinc oxide moisture content and protein content of flour decreased compared to unfortified flour. Quality attributes of fortified chapatti like flexibility, texture, and chewiness were reduced up to 15% as compared to unfortified flour. Fortification had deteriorative effects on the chemical stability of flour as well as on the texture attributes of the product. Also, the biologically active form-the ferrous form was converted to ferric, which affected bioavailability. Since whole wheat flour has significant levels of phytic acid, absorption and bioavailability of unencapsulated fortificants like iron, zinc is significantly reduced. Softness of Naan (a kind of food prepared from wheat flour) was reduced significantly by the electrolytic effect of iron on the dough proteins. Biscuits prepared from flour fortified with ferrous sulphate showed unpleasant sensory attributes, grey colour and disagreeable taste compared to the unfortified ones. At room temperature, the unencapsulated ferrous sulphate caused oxidation in the biscuits and deteriorated the quality of the fat in the product. Finger millet flour has also been used as a vehicle for ferrous fumarate and ferric pyrophosphate fortification. Bio-accessibility of both fortificants was significantly reduced mainly due to the presence of large quantities of phytate, tannin, and calcium in millet flour which inhibit the absorption of iron. The disadvantages associated with unencapsulated iron and other micronutrient fortificants can be overcome with encapsulation techniques.

In a study, milk was fortified with unencapsulated iron and encapsulated iron. Thiobarbituric acid (TBA) absorption which measures the fat oxidation products and is a measure of stability, was higher in milk fortified with unencapsulated iron. Similarly, microencapsulated iron whey protein complex was used to fortify yogurt, which had good sensory quality and suppressed the oxidised flavour of iron. Whereas, high TBA absorption was observed in yogurt fortified with unencapsulated iron. This was due to the interaction of iron with casein of milk and the presence of oxygen acted as pro-oxidant and triggered lipid oxidation. When oxidation occurs, free fatty acids accumulate and ultimately TBA absorption increases which is an indicator of oxidative rancidity.

A Water/Oil/Water emulsion: Emulsion of water in corn oil with Tween 60 as an emulsifier was prepared to encapsulate iron in the inner aqueous layer to overcome oxidation. Encapsulation efficiency of iron was 99.75% and TBA reactive substances (TBARS) production was negligible showing that encapsulated iron prevented the oxidation reactions that led to increased formation of TBARS. Another type of encapsulated iron uses a stable form of iron (iron pyrophosphate) which was encapsulated by spray drying using palm oil with 1% lecithin. When iron microcapsules of variable sizes were prepared and evaluated for their bioavailability, the highest bioavailability was observed with the microparticles with smallest particle size.

In a study, three kinds of yogurt-plain, yoghurt fortified with ferrous sulphate, yoghurt with iron whey protein complex, and yoghurt with microencapsulated iron whey protein complex were compared for stability and sensory characteristics. Yogurt fortified with ferrous sulphate was highly oxidised and metallic taste developed. The flavour and overall quality of yogurt fortified with microencapsulated iron-whey protein complex were similar to those of unfortified yogurt and were well accepted by the sensory panellists. In another study, ferric ammonium sulphate microcapsules were prepared using airless paint sprayer method. In this method, the emulsion of polyglycerol monostearate and iron salt was nebulised into a chilled solution tween 60. The resultant mixture was centrifuged and microcapsules were obtained. The encapsulation efficiency of microcapsules was 75%. Chemical lipid oxidation rate was high in milk fortified with unencapsulated iron. TBA absorption increased in milk fortified with unencapsulated iron after 12 days of storage.

Microcapsules containing ferric pyrophosphate, potassium iodide, and retinyl palmitate were prepared by using spray chilling technique. In this, ferric pyrophosphate (40% w/w) and lecithin (1% w/w) in hot molten palm fat were filled in spray tower, iodine salt, and retinyl particles were also added into the mixture. This mixture was transferred immediately to pre-cooled spray tower to avoid oxidation and the atomised particles were solidified. The size of microcapsules was 132 µm. The microcapsules were added in salt to prepare Triple fortified salt (TFS). There was no difference in colour or taste, and the overall acceptability was good.

Microencapsulation technique

Microencapsulation may be defined as the process of enclosing a substance inside a miniature capsule. Extremely tiny droplets, or particles of liquid or solid material, are packed within a second material or coated with a continuous film of polymeric material for the purpose of shielding the active ingredient from the surrounding environment. All three states of matter (solids, liquids, and gases) may be microencapsulated. core materials may be encapsulated so that the core material will be released either gradually through the capsule walls, known as controlled release or diffusion, or when external conditions trigger the capsule walls to rupture, melt, or dissolve. The substance that is encapsulated may be called the core material, the active ingredient or agent.

The material encapsulating the core is referred to as the coating, membrane, shell, or wall material. Microcapsules may have one wall or multiple shells. These capsules, which range in size from one micron to several 100 microns. Terms applied to the coating of the microcapsules include the wall, shell, external phase or membrane. Advantages of Microencapsulation: The primary reason for microencapsulation is either for sustained or prolonged drug release or to increase bioavailability. This technique has been widely used for masking taste and odour of many drugs to improve patient compliance. This technique can be used for converting liquid drugs into a free-flowing powder.

Microencapsulation protects encapsulated nutrients from oxidation due to exposure to moisture, light and other prooxidants. Incompatibility among the components of fortificant and food vehicle can be prevented by microencapsulation. Vaporization of many volatile bioactive compounds can be prevented by microencapsulation. Also, microencapsulation reduces toxicity and GI irritation. Alteration in site of absorption can also be achieved by microencapsulation. Microencapsulated vitamin A palmitate was reported to have enhanced stability. Microencapsulation decreases evaporation rate of the core material and also enables targeted delivery.

Composition and characteristics of microcapsules provides definite flexibility and utilization of these features often allows effectual design and development of the desired microcapsule properties. Controlled release of nutrients from microcapsule is achieved under specific conditions. Coating Materials: The coating material should be capable of forming a film that is cohesive with the core material, be chemically compatible and non-reactive with the core material and provide the desired coating properties, such as strength, flexibility, impermeability, optical properties, and stability. Film-forming, pliable, tasteless, stable. Non-hygroscopic, no high viscosity, economical. Soluble in an aqueous media or solvent, or melting. The coating can be flexible, brittle, hard, thin etc. Examples of coating materials: *Water soluble resins*- Gelatin, Gum Arabic, Starch, Carboxymethyl-cellulose, Hydroxyethylcellulose, Polyvinylpyrrolidone, Methylcellulose, Arabinogalactan, Polyvinyl alcohol, Polyacrylic acid. *Water insoluble resins* — Ethylcellulose, Polyethylene, Polymethacrylate, Polyamide (Nylon), Poly (Ethylene Vinyl acetate), and Cellulose nitrate, Silicones, Poly (lactidecoglycolide). *Waxes and lipids* — Paraffin, Carnauba, Spermaceti, Beeswax, Stearic acid, Stearyl alcohol, Glyceryl stearates. *Enteric resins*- Shellac, Cellulose acetate phthalate, Zein.

The process variables for effective encapsulation are as follows: Density, surface area, melting point, solubility, friability, volatility, crystalline nature, flowability of the core material, concentration and application rate of coating material, volume of air required to fluidize and support the core material, inlet and outlet temperatures. Evaluation of microencapsulation is done by the following methods- Surface morphology of the microcapsules by Scanning electron microscopy, bioactive compound content and activity determination, determination of % ingredient entrapment, bulk density, particle size, studies on in vitro dissolution, diffusion and stability.

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25. Seaweeds: Scope and potential

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Introduction

The marine environment is natural abode for a great variety of plants like organisms known as seaweeds or marine macrophytes or macroalgae. These marine macrophytes does not have true roots stems or leaves but the appearance resembles non-woody terrestrial plants and are widely distributed from tidal and intertidal regions to considerable depths of oceans. Seaweeds are integral part of marine ecosystem and serve as good source of food and provide habitat to many animals. Some of them grow faster than any other plant on earth and hence known as wonder plants. The seaweed anatomy refers to algal body, thallus; lamina or blade is the flattened structure resembles with the terrestrial leaf, sorus is spore cluster, pneumatocyst is air bladder an organ assists in flotation, stipe a stem-like structure which may or may not be present in all the seaweed, holdfast is a basal structure providing attachment to the substrate which resembles with the root of the terrestrial plants. The stipe and blade are sometime collectively called as the fronds. The seaweeds are classified on the basis of pigmentations in it. On the basis of the pigments there are three broad groups of seaweeds i.e., brown red and green botanist refer these groups as Phaeophyceae, Rhodophyceae and Chlorophyceae respectively. Brown seaweeds usually vary from smaller species to giant kelp which grow as large as 20 m long. The red seaweeds are usually smaller, generally ranging from a few centimetres to about a meter. Green seaweeds are also smaller in size similar to red seaweeds. The red seaweeds are not always red in colour they vary from red to purple and sometimes brownish red but are classified as red because of the pigments present in it.

The seaweeds are used as food source in Asian countries since time immemorial. The use of seaweed as food source is traced back to fourth century in Japan and to the sixth century in China. Today along with Japan and China, Republic of Korea are the largest consumer of seaweeds as food.

Various red and brown seaweeds are used as to produce hydrocolloids. A hydrocolloid is non-crystalline substance with very large molecules which dissolves in water to give thick viscous solution. Three common seaweed hydrocolloids are Agar alginate and carrageenan. Agar, Alginate and Carrageenan are carbohydrate (polysaccharides) that are used to thicken aqueous solution to form gels of varying degrees of firmness which is use to stabilize edible, cosmetic and other industrial products.

Seaweeds are known for their richness in polysaccharides, minerals and certain vitamins, but they also contain bioactive substances like polysaccharides, proteins, lipids and

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polyphenols with antibacterial, antiviral and antifungal properties. This gives a great potential to seaweed as a supplement in functional foods and nutraceuticals.

Seaweed as functional food and nutraceuticals

In recent years seaweed has gained importance as component of functional food and nutraceuticals ingredients by virtue of the biologically active compounds present in it. It is obvious that the seaweed grows marine ecosystem is in an extremely challenging environment where survival requires remarkably diverse biologically active compounds and a seaweed make these compounds through its metabolic process. These diverse metabolic compounds are well known as bioactive compounds and their activity is also linked to improving the human health by altering the metabolic process, quenching free radicals and through altering genetic expression of cellular process. Because of the immense beneficial activities of the primary and secondary metabolites obtained from seaweeds they are considered as future foods. Different compounds present is seaweed having nutraceutical properties are polysaccharides, proteins, small peptides, fatty acids, vitamins, minerals, polyphenols, flavonoids etc.

In 1989 Stephen De Felice defined nutraceuticals by combining the terms nutrition and pharmaceuticals. According to him "nutraceutical is a food or a part of food which provides medical or health benefits, including the prevention and /or treatment of a disease". He explained when a food is cooked or prepared using scientific intelligence, with or without the knowledge of how or why it is being used, it is called a functional food and when the food helps in prevention and/or treatment of disease (s) and/ or disorder (s), it is called nutraceuticals and thus a functional food for a consumer can be a nutraceutical for another consumer.

Polysaccharides

Cell wall of seaweed is primarily containing polysaccharides approximately it is up to 50% of the dry weight. The biochemical compositions of these polysaccharide vary greatly depending on several factors such as species, developmental stage, environmental factors, harvesting period, extraction protocol etc. On the basis of its position, seaweed polysaccharides are classified as cell wall polysaccharides and storage polysaccharides. Some of the Polysaccharides contain sulphate moiety in it and called as sulphated polysaccharides. The common polysaccharides in green seaweeds are collectively known as Ulvan. Polysaccharides in brown seaweeds are Alginate, Fucoidan and Laminarin whereas polysaccharides in red seaweeds are Agar, Carrageenan and Floridian starch. All these polysaccharides are used extensively in food, biomedical, cosmetics and other industrial uses.

Ulvan

Ulvans are the sulphated polysaccharides present in the cell wall of green seaweeds. Rhamanose, xylose, rhamanose 3-sulphate, xylose 2-sulphate, glucronic acids and iduronic acids are the main building block sugar moiety present in the Ulvans. The sulphate group present in the sugar moiety enhance the functionality of the Ulvan polysaccharides and make it suitable for use in pharmaceutical agriculture and other food and pharmaceutical uses.

Alginates

Hexauronic acids like mannuronic acid and glucronic acids are the main building block units of alginate. Alginates are one of the most abundant polysaccharides in the brown seaweeds and extensively used in food and pharmaceutical industry. In food industry alginates are used as gelling agent, emulsifying agent, stabilizer and encapsulating agent. Alginates are known to have activity in human colonic microflora, enhance intestinal absorption rate and also the glycemic and insulinemic responses of alginates are widely reported.

Fucoidan

Fucoidans are the cell wall polysaccharides of brown seaweeds mainly in Fucaceae and Limanariaceae families. It is a sulphated polysaccharide with L-Fucose as main sugar moiety present in it. It has several medicinal properties such as anti-proliferative, antiangiogenic etc. Antiproliferative activity of some fucoidian compound are in preclinical stage.

Laminarin

Laminarin is a good source of dietary fibre, is a water-soluble polysaccharide containing β-(1-3)-glucan with β-(1-6)-linkages of 20-25 units. It is also known for its anticancer properties.

Agar

Agar is a cell wall polysaccharide present in red seaweed. It is mainly extracted from Gelidium and Gracilaria species. Agar is a sulphated polysaccharide containing sulphated esters of D-and G-Galactose units. Agar is generally used as thickening and gelling agent in food and cosmetics industries.

Carrageenans

Carrageenans are sulphated polysaccharides found in the cell walls of the red seaweeds. Mainly extracted from *Kappaphycus alvarezii* and *Chondrus crispus*. Ammonium, Ca, Mg, K, and Na sulfated esters of d-galactose and (3,6)-anhydro-d-galactose units are responsible for the polysaccharide structure of carrageenans. Biological properties, chemical modification, and structural analysis of carrageenans have been reviewed previously. A fermented food "tofu" prepared with k/ι-hybrid carrageenans showed the highest rheological properties and carrageenan could be a practical food additive to modify the food textures.

Proteins and peptides

Seaweed contains different types of protein and peptide which differ from species to species and also depends factors like geographical location, environmental conditions, season habitat in which it grows, growth and developmental stage etc. It is reported that the among seaweeds the red seaweed contains the highest amount of protein followed by green seaweeds and brown seaweed contains the least amount of protein in it. Phycobilioproteins and lectins are the common type of functional protein present seaweeds.

Lectins are low molecular weight proteins attached with some carbohydrate or sugar moiety and play an important role in biological activities mainly intracellular communications. Lectins are also known to agglutinate the red blood cells. These glycoproteins are known to have antibacterial, antiviral, anti-inflammatory, anticancer and anti-HIV activities.

Phycobiliproteins are a family of reasonably stable and highly soluble fluorescent proteins found in red seaweeds. These proteins contain covalently linked tetrapyrrole groups that play a biological role in collecting light and, through fluorescence resonance energy transfer, conveying it to a special pair of chlorophyll molecules located in the photosynthetic reaction center. There are three major categories of phycobiliproteins: phycocyanins, allophycocyanins, and phycoerythrins, with phycoerythrins as a major, light-harvesting pigment in red seaweeds and regularly used as a fluorescent probe in scientific experiments. These properties allow some red seaweed species to survive in relatively deep water, depending on opacity and other conditions.

The nutritional value of protein depends on the amino acid content and the protein digestibility. Most seaweeds are rich in glycine, arginine, glutamic acid and alanine which are essential for human health. Seaweed proteins are reported to have different biological activity such as antihypertensive, antioxidant and antidiabetic effects. A short sequence of amino acids which are present in an inactive form and they break into shorter peptides during processing, gastrointestinal digestion or fermentation. These short chain peptides are biologically active which has nutraceutical potential to promote human health.

Fatty acids

During the last few decades, the lipid composition of seaweeds has raised considerable interest among researchers and nutritionists because of their high content of PUFAs, especially alpha linolenic acid (ALA) (18:3n-3), arachidonic acid (AA) (20:4n-6), eicosapentaenoic acids (EPA) (20:5n-3) and docosahexaenoic acid (DHA) (22:6n-3). This class of fatty acids are nutritionally important for humans and animals.

Vitamins

Vitamins are organic compounds required by human body for several essential biochemical and physiological processes. On the basis of its solubility, it is classified into two classes i.e., water soluble and fat soluble. Vitamins of B group and Vitamin C are water soluble whereas vitamin A and its provitamins-carotenoids with vitamin A activity, vitamins E, D and K are fat soluble. Though vitamins are required in very small quantities to fulfil the requirements but it is of great importance and people can consume vitamin containing foods as functional food and nutraceuticals. B group vitamins such as B1, B2, B12, vitamin C and fat-soluble vitamins E and β carotene, vitamin A activity have been reported from various seaweeds. Information on vitamin content and bioavailability of seaweeds vitamins are limited. Generally, seaweed contains both water soluble and fat-soluble vitamins. The vitamin profile of seaweed vitamins varies on species, geographical location, season, environmental condition etc.

Minerals

Cell wall polysaccharides and proteins in seaweed provide excellent binding sites for metal retention. Apart from the inherent metal binding capacity the accumulation of the metals in seaweed also depends on the bioavailability of metals in the surrounding water. Hence the seaweed contains high concentration of a wide range of diversified minerals. Most of the minerals required for human health such as potassium, sodium, phosphorous, calcium, iodine, magnesium, iron, and zinc are sufficiently available in different kinds of seaweeds and hence seaweeds have immense potential to be used as functional food and nutraceutical for the benefit of human health.

Polyphenols and flavonoids

Polyphenols are a group of heterogenous compounds with innumerable phenolic structures which differ structurally from simple molecules to highly polymerized compounds. These are major group of phytochemicals found in the human diet, such as fruits, vegetables, and other essential oils and other food derivatives. These polyphenolic compounds are classified on the basis of their source of origin, biological activities and chemical structure. In general polyphenols are classified as phenolic acids, flavonoids, stilbenes, lignans and other phenolic compounds. Flavonoids are classified into six major subclasses i.e., flavonol, flavanols, flavanones, flavones, isoflavones, and anthocyanins. Seaweeds are rich source of polyphenolic compounds mainly such as catechins, flavonols and phlorotannins etc. Green and red seaweeds are good source of phenolic acids, flavonoids and bromophenols. Evidence based on epidemiological, clinical and nutritional studies suggest that dietary polyphenols play an important role in human health. Regular consumption of polyphenols has been associated with reduced risk of different chronic diseases, including cancer, metabolic and neurodegenerative disorders and CVDs.

Conclusions

Seaweeds grows in huge quantity and there is no constraint of space and nutrient requirement for their growth in marine environment. In the recent era where people are struggling from different kinds of health issue many biologically active ingredients present in seaweed can be helpful in ameliorating the risk of different health issue. But still it is the need of the hour to further research on biologically active compound derived from seaweeds should be aim to study the efficacy of purified compound under different conditions to recognize their true potential.

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26. Innovations in Fishery Engineering

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Major areas of technological interventions in the field of fishery engineering includes 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.

1. Solar dryers

Fisherfolks 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 the 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 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, rains, 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

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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 the 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 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 fetches 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 by specially designed solar air heating panels and proper circulation of the hot air across the SS trays loaded with fish (Fig. 2). Food grade stainless steel is used for the fabrication of chamber and perforated trays which enable drying of fish 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 in night hours so that the bacterial spoilage due to partial drying will not occur. Improved shelf life and value addition of the product fetches higher income for the 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

ICAR-CIFT developed a low-cost, energy-efficient solar tunnel dryer for bulk drying of fish and fishery products. 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 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 fisherfolks.

Fig. 4. ICAR-CIFT Solar-tunnel dryer

2. 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 fishes easily. This equipment can remove scales from almost all types/sizes/ species of fishes ranging from marine to freshwater species like Sardine, Tilapia to Rohu. The machine is made of SS 304 and has 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 removal of scales. The water outlet is also provided to remove scales and water from the machine. An Electronic RPM meter was attached with the de-scaling machine which directly displays the RPM of the drum. The speed of the drum is a factor influencing the efficiency. The machine takes only 3-5 minutes to clean 10 kg fish depending on the size.

Fig. 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 fishes easily. This equipment can remove scales from almost all types/sizes/ species of fishes ranging from marine to freshwater species like Sardine, Tilapia to Rohu. This machine is made of SS 304 and has 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.

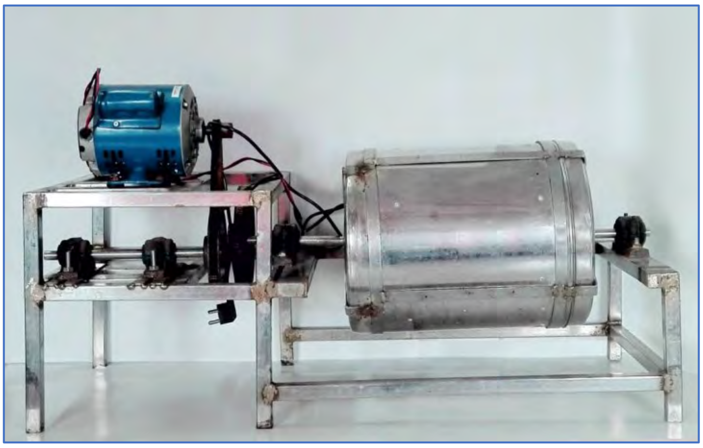

Fig. 6. Fish de-scaling machine with fixed drum speed

2.3. **Hand operated Fish descaling machine**

The fish descaling machine is designed and fabricated for removing the scales of fishes easily. This equipment can remove scales from almost all types/sizes/ species of fishes ranging from marine to freshwater species like Sardine, Tilapia to Rohu (Fig. 7). This machine is made of SS 304 and has a 5 kg capacity. The body is fabricated in 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 in the side to rotate the drum manually (Delfiya et al. 2019).

Fig. 7. Hand operated fish de-scaling machine

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 specimen 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

3. 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 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 fishes coming out of de-scaler is free of scales, dirt, or slime. It also reduces human drudgery and avoids cross-contamination, consumes lesser time. 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. 8. Refrigerated mobile fish vending kiosk

4. Electronics and Instrumentation

ICAR-CIFT identified the vast scope of electronics and instrumentation for fisheries technological investigations and started research and development activities. This resulted in a series of instruments for systematic monitoring, analysis, and assessment of the marine environment including the performance of the 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 to PC, wireless transmission to distant points, *etc.*
Some of the instruments, which has got great attention and acceptance are as follows: environmental data acquisition system, freezer temperature monitor, salinity temperature-depth meter, hydro-meteorological data acquisition system, warp load meter, solar radiation monitor and integrator, 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.

5. 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 replacement of outdated technologies, 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 as 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 wastes 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 the 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.

6. 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 facilities 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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27. Microbiological aspects of fish and fishery products

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Introduction

Fisheries contributes to the global nutritional and food security immensely. According to the estimate of 2018, the live weight of fish produced from captured fisheries and aquaculture activities has crossed 178.5 million tonnes. Captured fisheries and aquaculture contributed to 54% and 46% of its productions. Out of the 178.5 million tonnes produced, 156.4 million tonnes are used for human consumptions for over 7.6 billion population across the globe with per capita consumption of over 20.5 kg per year. Among which 37.6% are in traded for exports for value 164.1 USD (FAO, 2020).

The most important exporting countries across the world are EU, China, Norway, Vietnam, Chile, India, Thailand, United States, Canada, Ecuador, and Russia. EU and China take shares around 56 billion USD and other countries 58 billion USD in terms of values of export. Major countries importing seafood are USA, Japan, China, Spain, Vietnam, France, Italy, Germany, Sweden and South Korea. The countries China, Vietnam, United States, are involved in both import and export.

Definition:

Seafood are edible aquatic animals which excludes mammals covering freshwater and sea for food purpose. Aquatic food or *blue foods* are food originating from animals, plants, and microorganisms of water bodies.

Microbes and Microbiology

Living organisms that multiply frequently and spread rapidly and very tiny in nature that cannot be seen in naked eye are microorganisms or microbes. Majority of the organisms are existing as beneficial flora in each and every niche and contributing to the basic biogeochemical cycle of the life. However, some of the microbes do exists as pathogenic to either human or animals including the fish/shellfish. Examples are Bacteria (e.g., *Staphylococcus aureus*, Streptococcus pneumoniae), viruses (e.g., Measles, Mumps), fungi (e.g., *Candida albicans*,), parasites (Coccidia etc) which are pathogenic to human.

In general, to exception of commercially sterile and other pro, pre and synbiotics food products, food have the proximity of getting contaminated to various microbes during entire production and processing chain. The raw food in general has the highest culturable bacterial concentrations, followed by minimally and fully processed foods. Minimally or fully processed food including ready-to-eat food contamination depends on the level of sanitary hygiene followed during the processing and preservation steps.

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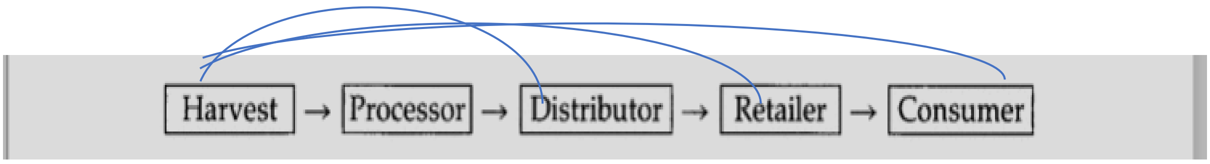

Fig.1. Steps contributes to the entry of microbes in the seafood chain

The food with acceptable microbiological quality range may also serve as the sink for the development of antibiotic resistances through bacteria, bacteriophages, bacterial DNA and mobile genetic elements, some of which may include AMR genes. Hence, the food chain ecosystem may be conducive niches for gene transfer, selection and persistence of AMR bacteria and this route cannot be generally disregarded. In the typical seafood production chain, the fish which are harvested has many distributions step viz., harvest to consumer, harvest to processor, harvest to retailers, harvest to distributors and retailers (Fig.1.). The more the number of handling steps, the more the probability of microbes being contaminated into the food production chain.

In the seafood production chain, the food fish gets harvested either from aquaculture farms or from capture fisheries activities. The harvested food fish gets transported to retail market, hypermarket, or unorganized retail vendors. The harvested food fish may be taken to the fish processing factories within their state or to the neighbouring state and get processed for domestic or export purposes. The major contributing factors which results in the contamination of pathogens in to the seafood are water and ice. In order to break the chain of contamination of these microbial pathogens into the seafood production and distribution channel, the places mentioned in the figure.2 has to be implemented.

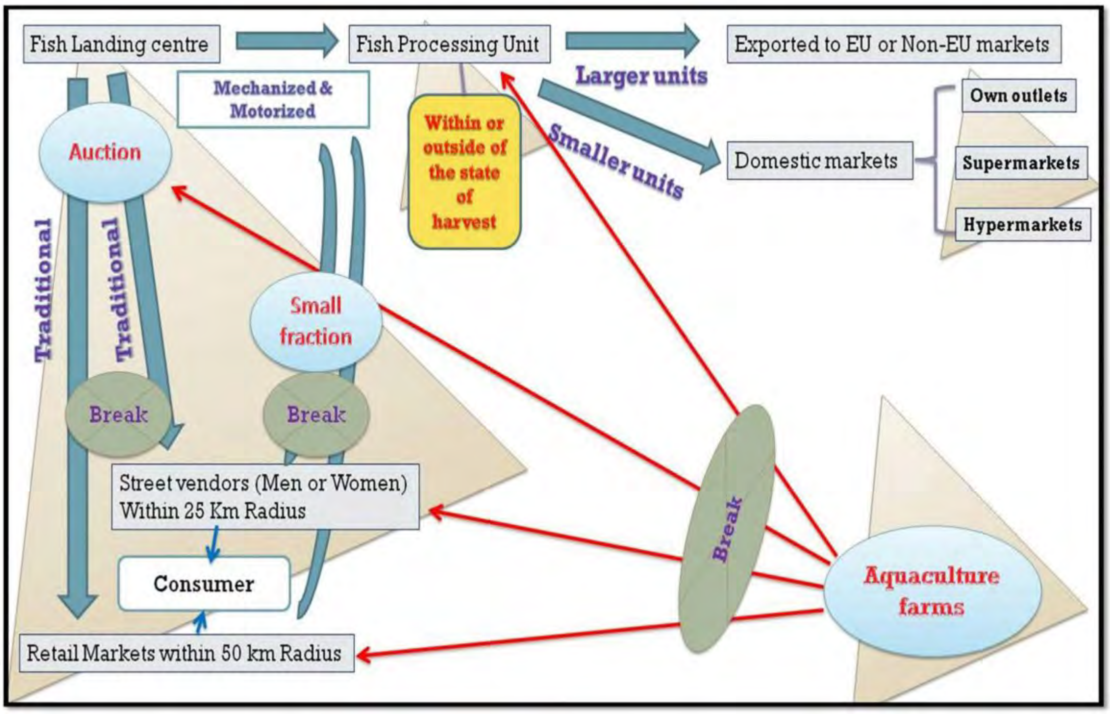

Fig. 2. Typical seafood production and distribution chain with major break point places for preventing contamination of microbial pathogens.

The seafood meant for human consumption either for domestic market or for exports has to be ascertained for predefined quality. In India, the seafood or fish/fishery products meant for domestic consumption is regulated by Food Safety and Standards Authority of India (FSSAI) and seafood meant for export purpose is handled by Export inspection council (EIC).

The end product (fish and fishery products) has to be examined for the absence of hazards. "Hazard in food is defined as anything that could contaminate food and cause illness or injury, or could otherwise violate established food safety program criteria if left uncontrolled". Hazard in the food is classified into three categories viz., physical, chemical and biological. A physical hazard is any foreign matter unintentionally introduced to food or a naturally occurring object which could cause illness or injury to the person consuming the food item. Natural and manufactured chemicals can cause people to become sick if they have contaminated food at the source or during processing. Chemical hazards can be divided into two categories: chemical agents and toxic metals. While physical and chemical hazards have potential to cause foodborne illness, the majority of foodborne illnesses result from biological hazards such as bacteria, viruses, and parasites (referred to collectively as pathogens). CDC has identified 31 different pathogens known to cause foodborne illness.

These hazardous microbes are classified once again as severe hazards, moderate hazardous with limited spread and moderately hazardous with extreme spread.

Examples of severe hazard are *Clostridium botulinum* types A, B, E, and F, *Shigella dysenteriae*, *Salmonella* Typhi, *Salmonella* Paratyphi A, B, Hepatitis A and E, *Brucella abortis; B. suis*, *Vibrio cholerae* 01, *Vibrio vulnificus*, *Taenia solium* and *Trichinella spiralis*.

Among these severe hazards, the *Clostridium botulinum* types A, B, E, and F, *Shigella dysenteriae*, *Salmonella* Typhi, *Salmonella* Paratyphi A, B, Hepatitis A and E, *Vibrio cholerae* 01, *Vibrio vulnificus* are relevant to seafood.

Examples of moderate hazards with extreme spread are *Listeria monocytogenes*, *Salmonella* spp., *Shigella* spp., Diarrheagenic *Escherichia coli*, *Streptococcus pyogenes*, Rotavirus, Norwalk virus group, *Entamoeba histolytica*, *Diphyllobothrium latum*, *Ascaris lumbricoides,* and *Cryptosporidium parvum*. Among these moderate hazards, *Listeria monocytogenes*, *Salmonella* spp., *Shigella* spp., Diarrheagenic *Escherichia coli*, *Diphyllobothrium latum* are very relevant to the seafood.

Examples of moderate hazards with limited spread are *Bacillus cereus*, *Campylobacter jejuni*, *Clostridium perfringens*, *Staphylococcus aureus*, *Vibrio cholerae, non-O 1*, *Vibrio parahaemolyticus*, *Yersinia enterocolitica*, *Giardia lamblia* and *Taenia saginata*. Among these, *Bacillus cereus*, *Campylobacter jejuni*, *Clostridium perfringens*, *Staphylococcus aureus*, *Vibrio cholerae, non-O 1*, *Vibrio parahaemolyticus,* and *Yersinia enterocolitica* are very relevant to the seafood industry.

For the seafood industry, the pathogens such as *Salmonella* sp. *Yersinia* spp., *C. Botulinum*, *S. aureus*, *L. monocytogenes*, ***Vibrio* spp. (*V. cholerae*, *V. vulnificus, and V. parahemolyticus*),** *Aeromonas* sp, *Campylobacter* sp and *Bacillus cereus* are very important. Few of the pathogens are emerging in nature and few are endemic to the seafood production system and others are reemerging in nature.

Examination of the biological hazards in the seafood

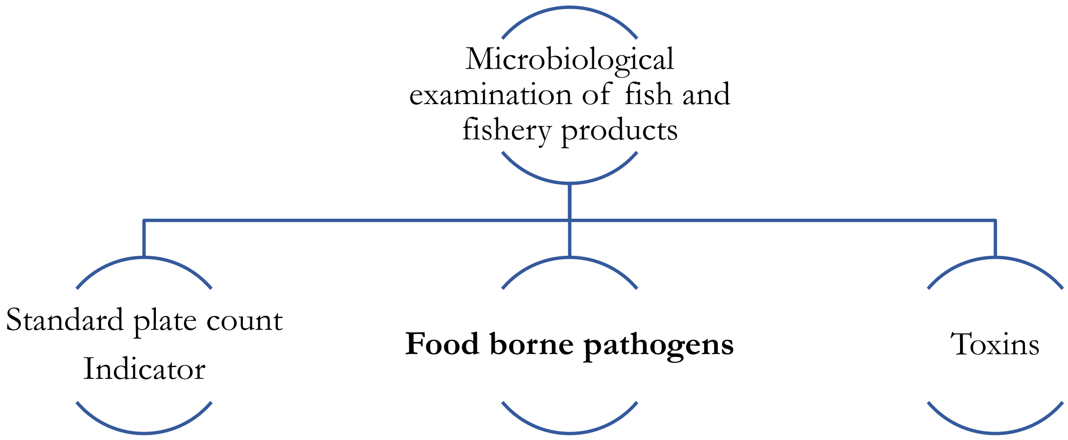

Fig. 3. Microbiological examination of seafood

Microbiological examination of seafood can be categorized into examination for indicator organisms, examination for the pathogens and or its toxins (Fig. 3).

Microbiological examination of seafood has few important steps (Fig. 4)

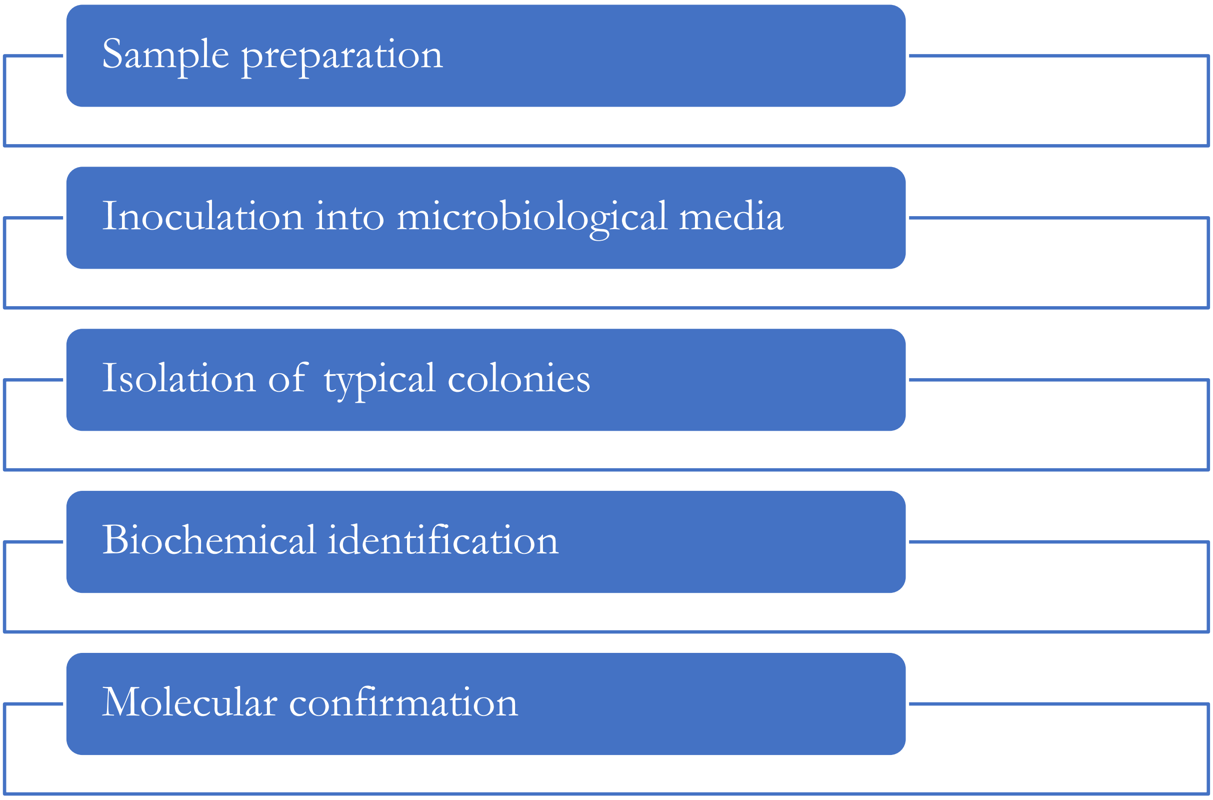

Fig. 4. Basic steps involved in the microbiological examination of seafood

For the microbiological examination of seafood, the laboratory should have these facilities. Sample receiving room, Sample processing room, Media preparation room, Media sterilization room, Inoculation room, Incubation room, Identification room, Decontamination and washing room.

Instrumentation required for setting up of microbiological testing facility for food includes Incubators / refrigerated / Co2/ BOD, Hot air oven, Autoclaves, Homogenizer / Stomacher / Mixer, Colony counter, Water bath, weighing balance, Thermal cycler including gradient, Gel electrophoresis system, Gel documentation system, Biosafety cabinet, Refrigerator centrifuges, Refrigerated shaker incubator and Microscope. A typical work flow in any standard microbiological laboratory is presented in Figure 5.

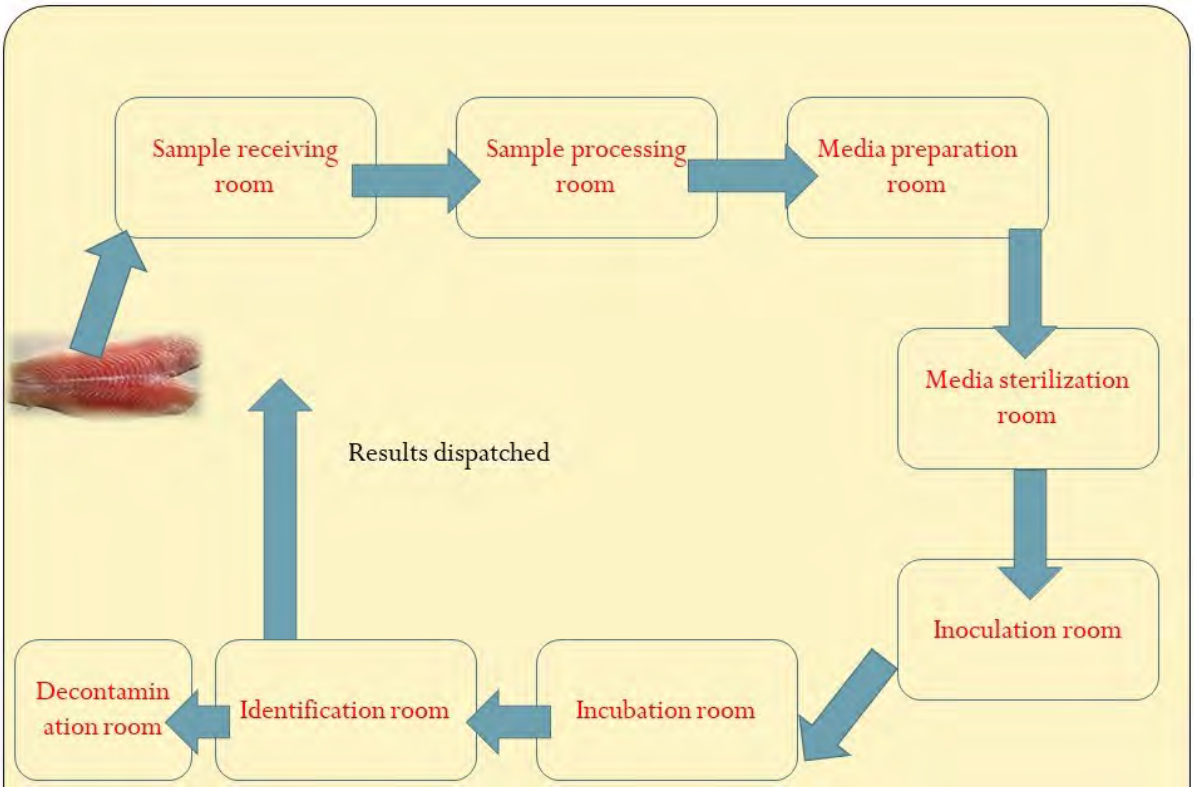

Fig. 5. Typical work flow and rooms involved in the microbiological testing.

For the microbiological examination of seafood (fish and fishery products) the laboratory should follow the exporting or importing countries guidelines viz., FSSAI – India, BAM – USA, ISO guidelines – EU countries and other based on the country's regulatory requirements.

To conclude, Fish and fishery products are most traded commodities across globe, For sustainability – Quality of food has to be maintained, Hazards – Biological hazards has to be controlled, Places where the biological hazard entry can be prevented should be defined in the seafood production system, Layout of microbiology laboratory and instrumentation involved in the testing varies based on the laboratory requirements, and the Guidelines sorting for each matrix testing is highly essential for the laboratory involved in the testing.

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28. Prophylactic Health Products in Aquaculture

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Introduction

There is widespread use of antibiotics in aquaculture and large variation exists between countries and regions on the use of antibiotic in the field. The usage of antibiotic in different countries varies between 1 g for every1000 kg seafood produced in Norway to 700 g per 1000 kg of production in Vietnam. Based on the estimates nearly 500–600 tons of antibiotics is used in shrimp aquaculture. The most widely used antibiotics used in aquaculture are oxytetracycline, sulphadiazine and florfenicol and about 67 antibiotics are applied in aquaculture based on a study in 15 countries. It is difficult to assess the use of antimicrobial agents in aquaculture since there are lot of differences in the regulations, distribution and registration of antimicrobials between countries. Also, there is lot of variation in the antibiotics used between different countries. With the increase in the use of antibiotics in aquaculture as prophylactics, the risk of antimicrobial resistance has gone high, thereby the medications have become less effective. The genes responsible for antimicrobial resistance may get transferred from aquatic animals or environment to terrestrial livestock and to human and vice-versa. This leads to adverse effects on aquatic environment and health of human and animals. Intensified aquaculture resulted in farming that promotes indiscriminate use of antibiotics, resulting in antibiotic residues in aquatic products. Almost 75% of the antibiotics given to aquatic animals are wasted due to defecation or dispersal into the surrounding water. With the growth of intensive aquaculture, there is increased incidence of several bacterial diseases, resulting in further use of antibiotics. Presence of antibiotics in aquatic environments can affect the diversity of bacteria, including the taxa that are involved in primary productivity and carbon and nitrogen cycling. Pathogens may acquire antibiotic resistance genes from the environmental resistome leading to long term health consequences. The environment gets polluted due to unrestricted use of antibiotic in the environment, thereby there is selection and distribution of antibiotic resistant bacteria, and also changes in the microbial ecosystems.

Use of probiotics

Probiotics that control the pathogens in aquatic animal and environment through different mechanisms are considered as alternative to antibiotic treatment. Probiotics were used in human and animal nutrition since long. The use of probiotics in aquaculture is very recent.

Probiotics are defined by FAO/WHO (2001) as “Live microorganisms, which when consumed in adequate amounts, confer a health benefit for the host”. Aquaculture probiotics can be defined as “Live microorganisms provided in adequate amount *via* the diet or rearing water that confer a health benefit for the host fish/shrimp by modifying the host-associated or ambient

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microbial community."

Mechanism of action

Probiotics acts through different mechanisms including competitive exclusion of pathogens, as a source of nutrients, contributes enzymes for digestion, enhanced immune response and different other mechanisms.

The probiotic concept was initially developed for terrestrial animals that are completely different from the aquatic animals. The gastrointestinal tract of the larvae of fish and shrimp are exposed to external environment at a very early life stage unlike in terrestrial animals that undergo embryonic development in the amnion. The initial trials for the use of probiotics in aquaculture feed was with a probiotic strain *Bacillus toyoi*, used in terrestrial animals. The bacterial strain was found to reduce mortality of Japenese eel infected by *Edwardsiella* sp.,. Most probiotics used in aquaculture belong to the genus *Bacillus,* lactic acid bacteria (*Lactobacillus* and *Carnobacterium*), *Vibrio*, and *Pseudomonas*, although other genera or species have also been used.

Due to the ability of the probiotic microorganism to produce various digestive enzymes including amylases, proteases, and lipases, etc., and to provide nutrients (amino acids, fatty acids, vitamins etc., they contribute to the feed utilisation, digestive process and the absorption of nutrients resulting in improved health and growth performance of aquatic animals.

Supplementation of probiotic was found to improve the appetite and increase the digestibility of nutrients. Probiotics enhances the survival and growth of the aquatic animals by improving the feed efficiency in aquatic animals and maintaining balance of intestinal microbes and stimulating digestive enzymes resulting in improved nutrient absorption and utilisation. Inclusion of probiotics in diets of aquatic animal results in increased immune response by interaction between intestinal epithelial cells and bacterial cells. Probiotics can also stimulate the immune system against infectious diseases. Probiotics can increase sodium and water absorption, produce short-chain fatty acids and support host health.

Probiotics also interact with pathogenic bacteria and are sometimes antagonistic to pathogenic bacteria by directly inhibiting or by resisting colonisation and also by reducing the incidence of opportunistic pathogens. Probiotics also enhances host health by immune modulation.

Probiotics have bactericidal activity on the intestinal pathogenic bacteria of the host and are able to prevent multiplication of opportunistic pathogens. The bactericidal activity of the probiotic bacteria is due to the production of molecules having bactericidal activity.

Probiotics can also be used for improving the water quality of the rearing water, by modifying the microorganisms and inhibition of pathogenic bacteria in the aquaculture environment which results in improving the health status of aquatic animals.

Need for regulation in probiotic

The application of probiotics in aquaculture shows promise, but needs considerable efforts of research. The quality and safety of the commercial aquaculture probiotics sold in the market in many countries are under question as this emergent market lacks appropriate regulatory framework. Improper labeling, mismatch with claims, presence of infectious agents, antibiotic residue, high AMR profile, fake health claims and safety issues of probiotics raises concern on the availability of a good aquaculture probiotic in market. Most of the probiotics with unjustified claims comes at a high-cost relative to budget of smallholder producers, imposing an economic burden. Since the aquaculture probiotics are directly applied to farms and are released to open environment, risk related to the propagation of hazard and health-safety threats are high.

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29. Hygienic indicator bacteria in sea-foods and aquaculture

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INTRODUCTION

Indicator bacteria are types of bacteria that are used to provide an indication of hygienic status of the seafood whether it's of poor hygiene, or inadequate processing and or post- process contamination. If it's free of indicator bacteria in seafood and aquaculture products provides a degree of quality assurance that the fishery products are hygienically good and followed proper processing methods. Whereas, the presence of any kind of indicator bacteria in the fishery products clearly reveals that the chances of recent contamination during the pre-harvest and post-harvest processing by the fecal contaminated waters, infected workers, utensils, and equipments etc. Traditionally, the indicators bacteria are related to in-sanitation/ unhygienic and public health concerns. But over the years, the use of indicator organisms has been extended to provide evaluations of the quality and safety of seafood and aquaculture products. The indicator bacteria in seafood and aquaculture products mainly belong to enterobacteriaceae and coliforms group of bacteria. Traditionally, indicator micro-organisms have been used to suggest the presence of pathogens (Berg, 1978) and so posed safety concerns (Smoot and Pierson, 1997). Moreover, several studies revealed a lack of correlation between the presence of indicators and pathogens (Martin et al., 2016 & Miskimin et al., 1976), hence the usefulness of indicators is less significant in assessing product safety. Some instances no direct correlation of the presence of certain coliforms as an indicator of fecal contamination (Trmcic et al., 2016 and Boor et al., 2017). *E. coli* is considered to be the appropriate indicator fecal contamination and a hygiene indicator since it is the most likely the origin of the intestine (Smoot and Pierson, 1997 and Trmcic et al., 2016). Moreover, ensure food safety by implementing food hygiene controls at each stage of food handling throughout the food chain.

Criteria for the Selection of Indicator Organisms

The following factors should be considered while selecting an indicator organism depending on the context to be looked in to as suggested by the International Commission on Microbiological Specifications for Foods (ICMSF):

Presence of the indicator reflects a defect in the process or practice or a potential for spoilage.

1. Survival or stability of the indicator should be similar to or greater than the hazard or spoilage organism.

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2. Growth characteristics of the indicator should be similar to or faster than the hazard or spoilage organism.
3. Identifiable characteristics of the indicator should be stable
4. Method for detection and or/ quantitation should be easy, rapid, inexpensive, reliable, sensitive and validated does not risk analysis health; and is suitable for in-plant use.
5. Quantitative results should show a correlation between the concentration of the indicator and the level of the hazard or spoilage organism.
6. Results should be applicable to process control.

The indicator micro-organisms include the general microbial Process Indicators, Faecal Indicators, and Index and Model Indicator organisms. The ***Process Indicator*** is a group of organisms that indicates the efficacy of processing steps at different levels and are tested by Total Plate count (TPC)/ Total heterophilic count or total coliforms (MPN method). ***Fecal Indicator*** is a group of organisms that indicates the presence of fecal contamination and could be tested by fecal coliforms, thermotolerant coliforms (MPN method) and *E. coli* (EMB and IMViC test). An ***Index*** and ***model organisms*** is a group of organisms that indicates the presence of pathogens such as *E. coli* as an index for Salmonella and coliphages as the model of human enteric viruses. The Pathogenic ***Indicator*** bacteria viz., Coliforms, Fecal coliforms, *E. coli*, *Klebsiella*, *Enterobacter*, *Citrobacter*, Fecal Streptococci, Sulphite reducing clostridia, *Clostridium perfringes*, Bifidobacteria, Bacteriophages, coliphages and Bacteroides fragilis bacteriophages etc, are associated with food poisoning. In addition, pathogenic viruses, protozoa and parasites are also present in fecal matter. Fecal contamination is mainly from the sewage of human sources, livestock, poultry manure, pets and wildlife. Infection caused by these pathogens is mainly depending on the level of microbial load and stage of contamination.

Types of Indicator bacteria

Different types of bacteria are found in the gastrointestinal tracts and feces of animals and humans. The faecal coliforms, *E. coli*, and Enterococcus spp., are used as hygiene indicators (Frahm and Obst, 2003). Indicator bacteria are a group of bacteria indicates for the possible presence of pathogens and reflecting the unhygienic/in-sanitary status of seafood safety in processing (Mossel et al. 1995). In general, assess the indicator bacteria most often used to assess food sanitation (Jay 1992). There is no universal agreement on which indicator microorganism(s) is most useful, nor are there federal regulations mandating a single standard for bacterial indicators. Thus, different indicators and different indicator levels identified as standards are used in different states, countries, and regions. Today, the most commonly measured bacterial indicators are total coliforms (TC), faecal coliforms (FC), and enterococci (EC). More recently, *E. coli* (a subset of the FC group) and EC were established as preferred indicators (Noble et al. 2003).

The indicator bacteria include **total coliforms** (Gram-negative, non-spore-forming, oxidase-negative, rod-shaped, facultatively anaerobic, ferment lactose), **thermotolerant coliforms** (Produce gas and acid from lactose at 44.5°C ± 0.2°C within 24 ± 2 hrs) and fecal coliforms (Produce gas and acid from lactose at 37°C ± 0.2°C within 24 ± 2 hrs), which are found in the intestinal tracts of warm-blooded animals. Total coliforms were used as fecal indicators by public agencies in the US as early as the 1920s. These organisms can be identified based on the fact that they all metabolize the sugar lactose, producing both acid and gas as a by-product. Fecal coliforms indicate that recent fecal contamination is being occurred. Escherichia coli (*E. coli*) and enterococci (all fecal streptococci grow at pH 9.6, between 10°C and 45°C, 6.5% NaCl and hydrolyzing 4-methlumbelliferyl-B-D-glucoside of thallium acetate, nalidixic acid and 2,3,5-triphenyltetrazolium chloride) are commonly used as indicators. The **Sulphite reducing clostridia** (SRC)-Gram-positive, spore-forming, non-motile, strictly anaerobic rods that reduce sulphite to H_2S), ***Clostridium perfringes*** (As for SRC but also ferment lactose, sucrose, and inositol with the production of gas, produce stormy clot fermentation with milk, reduce nitrate, hydrolyse gelatin and produce lecithinase and acid phosphatase), **Bifidobacteria** (obligatory anaerobic, non-acid fast, non-spore-forming, non-motile, Gram positive bacilli which are highly pleomorphic and may exhibit branching bulbs-bifids, clubs, coccoid, coryneform, V and Y forms and all are catalase- negative and ferment lactose, **Bacteriophages** (bacterial viruses and are ubiquitous in the environment and are used as model to human enteric viruses, eg. Somatic coliphages, male-specific RNA coliphages and pahges infecting Bacteroides fragilis), **Coliphages** (Somatic coliphages attack *E. coli* strains via the cell wall and sex pili) and **Bacteroides fragilis baeriophages** (infect most abundant bacteria in the gut, eg. *B. fragilis* HSP40) etc, are also considered as fecal indicator microorganisms.

Development of Indicators for the Identification

Indicator organisms are one of the important constituents of microbiological testing programs conducted both by regulatory agencies and the exporters and its presence reflects the presence of pathogens and unhygienic/ in-sanitation practices are being followed and also a chance of a process failure along the food chain. The presence of indicator bacteria on seafood may reflect quality attributes such as taste, odour, texture and color and shelf life. So the indicator bacterial load of a fishery product significantly determines its quality. Many foods provide an environment conducive to microbial growth, and indicator counts in such foods may reflect the time and conditions of storage. The indicator bacterial tests are used to ensure the seafood are microbiologically stable and aesthetically acceptable. These testes are assessed in an appropriate context, microbial ecology, intrinsic and extrinsic physical and chemical factors that influence the growth, process history, and storage conditions of the product. The indicators are generally categorized in to safety and quality indicators. ***Safety indicators*** suggest that a microbial hazard may exist, and their presence may cause no or minimal hazard. ***Quality indicators*** are used to assess the hazard that influences the product acceptability viz., shelf life, organoleptic characteristics, spoilage, etc. The ICMSF has noted that the selection of an indicator must be considered carefully with an understanding of how to interpret the results of indicator testing. Indicators are a compromise, representing an analytical substitute for the detection of the target hazard or concern directly. They can never be used to prove the presence or absence of the target. The following are tests to be carried out to assess the indicator bacteria in the seafood and aquaculture products

1. **Aerobic plate count (APC):** APC is one of the most commonly used indicator tests. The APC cannot be used as a safety indicator because there is no correlation between APCs and the presence of pathogens or their toxins but maybe a quality indicator for a type of sample. The APC of a product may reflect the microbial load of the seafood and its products and reflects extend of freshness or level spoilage taken place. If the APCs are beyond the accepted limit, tests for specific spoilage microorganisms for determining the acceptability of the products. APC can indicate adherence to sanitation, Good Manufacturing Practices (GMPs) and product acceptability. **APC Detection and enumeration**: International Organization for Standardization (ISO 4833) calls for aerobic incubation on plate count agar at 30°C for 72 hours. The FDA's BAM recommends 35°C for 48 hours for non-dairy foods. The Standard Plate Count, which is used for estimating bacterial populations in dairy products, strictly specifies 35°C for 48 hours. The 'pour plate' method for the APC is officially recognized (AOAC 966.23C; ISO 4833). The 'spread plate' technique is generally easier to perform and may have other advantages: different colony morphologies may be recognized, translucent media are not required, and microorganisms are not exposed to the heat of the molten agar. Other rapid methods have been officially recognized,

including the use of the hydrophobic grid membrane filter (HGMF; AOAC 986.32), pectin gel (AOAC 988.18), and dry rehydratable film (AOAC 990.12). SimPlate® Total Plate Count, which uses colorimetric detection of growth in micro wells to determine the most probable number (MPN) of the microorganisms, is the most recent method to receive official status (AOAC2002.07).

2. **Coliforms and *E. coli*: C**oliform is a group of organisms (C*itrobacter, Enterobacter, Escherichia* and *Klebsiella)* and it is not a valid taxonomic classification but is defined functionally by the lactose fermentation. Coliforms are as Gram-negative, oxidase-negative, aerobic or facultative anaerobic non-spore-forming rods, able to grow in the presence of bile salts, and which ferment lactose to produce acid and gas within 48 hours at 37°C. The *Citrobacter, Enterobacter,* and *Klebsiella* species are also normal inhabitants of plants and the environment and so does not necessarily indicate fecal contamination. Hence the coliform test is not valid for the indicator of faecal pollution so the faecal coliform test is evolved. Fecal coliform could able to grow by fermenting lactose at 44.5–45.5°C is considered as the fecal coliforms and is also referred to as thermotolerant coliforms. However, the species like *E. coli* have the capacity to grow at this temperature and are found in the natural environment and also in all mammalian faeces. So, the faecal coliforms are not specific indicators of faecal pollution. The coliform groups and *E. coli* are taken into account in seafood and aquaculture products as hygienic indicators/ sanitation and process integrity indicators and for Hazard Analysis Critical Control Point (HACCP) verification.

Coliforms: The use of bacteria as indicators of the sanitary quality of water probably dates back to 1880 in human faeces (Geldreich 1978). In 1891, Franklands came up with the concept that organisms characteristic of sewage must be identified to provide evidence of potentially dangerous pollution. In 1893, 'Wurtz method' of enumerating *B.* coli by direct plating of water samples on litmus lactose agar was being used by sanitary bacteriologists, using the concept of acid from lactose as a diagnostic feature. This was followed by gas production, with the introduction of the Durham tube (Durham 1893). The sanitary significance of finding various coliforms along with streptococci and *C. perfringens* were recognised by bacteriologists by the start of the twentieth century (Hutchinson and Ridgway 1977). MacConkey (1905) described his now- famous MacConkey's broth, which was diagnostic for lactose-fermenting bacteria tolerant of bile salts.

Coliform identification schemes: Various classification schemes for coliforms have emerged. MacConkey (1909) recognised 128 different coliform types. Bergey and Deehan (1908) identified 256. In the early 1920s, differentiation of coliforms had come to a series of correlations that suggested indole production, gelatin liquefaction, sucrose fermentation and the Voges– Proskauer reaction were among the more important tests for determining faecal contamination (Hendricks 1978). These developments culminated in the IMViC (Indole, Methyl red, Voges–Proskauer and Citrate) tests for the differentiation of so-called faecal coliforms, soil coliforms and intermediates (Parr 1938); these tests are still in use today. Simpler to identify coliform group, despite being less faecal-specific and broader (*Escherichia, Klebsiella, Enterobacter* and *Citrobacter* were considered the most common genera) was targeted. One of the first generally accepted methods for coliforms was called the Most Probable Number method (MPN) by Multiple-Tube Fermentation Test.

Detection of Coliforms and *E. coli:* Both quantitative and qualitative methods are described for determining total coliforms and faecal coliforms and is mainly by lactose fermentation and resistance to bile salts. Colony counts of the coliform group are obtained from violet red bile lactose (VRBL) agar (ISO 4832; ISO 5541/1).

The MPN method for enumeration of total coliforms as the organisms that ferment lactose to produce acidic condition and change the colour of the medium to yellow within 24 ± 2 hours when incubated at 35.0 ± 0.5°C on MacConkey Broth and utilize BGLB (2%) by the observable growth and gas production within ± 2 hours of incubation at 35.0 ± 0.5°C. **Fecal coliform bacteria** are defined as the organisms that grow and produce gas in *E. coli* broth (EC broth) in 24 ± 2 hours when incubated at 35.0 ± 0.5°C. ***E. coli*** are defined as the organisms that produce growth and gas production in tryptone broth (Indole medium) in 24 ± 2 hours when incubated at 44.5 ± 0.2°C and is confirmed on Eosine Methylene Blue agar (a sterile platinum loopful of culture from EC broth is streak-dilution method and Incubated at 37°C for 18-24 hrs produces well- isolated colonies, 2-3mm dia with a greenish metallic sheen by reflected light & dark purple centre by transmitted light and **IMViC** test (**Indole**- Degrade the amino acid tryptophan and produce indole, **Methyl Red**- *E.coli* use the mixed acid pathway, which produces acidic end products such as lactic, acetic, and formic acid. These acidic end products are stable and will remain acidic. When methyl red is added, if acidic end products are present, the methyl red will stay red, **Voges–Proskauer** - Utilization of glucose to acetyl methyl carbinol (acetoin) and it will react with alpha-naphthol (VP reagent #1) and potassium hydroxide (VP reagent #2) to form a red color and **Citrate utilization**- Organisms which can utilize citrate as their sole carbon source by the presence of enzyme citrase or citrate-permease and convert the ammonium dihydrogen phosphate to ammonia and ammonium hydroxide-alkaline environment. At pH 7.5 or above, bromthymol blue turns royal blue as positive. So the IMViC tests for *E.coli* as +, +, - and -).

3. Faecal streptococci and enterococci: A group of Gram-positive coccoid bacteria known as faecal streptococci (FS) and investigated as an important pollution indicator bacterium.

Faecal streptococci: Until 1957, with the availability of the selective medium that enumeration of FS became popular. Since then, several media have been proposed for FS and/or enterococci to improve on the specificity. Taxonomically FS are represented by various *Enterococcus spp., Streptococcus bovis and S. equinus* (WHO 1997). *Of the faecal streptococci, the* preferred indicators of faecal pollution are the enterococci. The predominant intestinal enterococci are *E. faecalis*, *E. faecium* and *E. durans.* In addition, other *Enterococcus species* and some species of *Streptococcus* (*S. bovis and S. equinus)* may occasionally be detected. These streptococci, however do not survive for long in water and are probably not enumerated quantitatively. Thus, for water examination purposes enterococci can be regarded as indicators of faecal pollution, although some could occasionally originate from other habitats.

Detection of Fecal streptococci are defined as the organisms that produce red or pink colonies within 48 ± 2 hours when incubated at 35.0 ± 0.5°C on Kennel Fecal Streptococcal medium.

Enterococci: The presence of *Enterococcus* group, which is a subgroup of the faecal *Streptococci*, serves as a valuable bacterial indicator for determining the extent of faecal contamination. *Enterococci* also have been described as spoilage micro-organisms and cross-contaminants during fish processing. If the numbers are high, indicates poor hygiene and reflects that either properly handled or processed properly. There are no standards set for the minimum and maximum count of *enterococci* because their counts vary with different stages of processing. *Enterococci* can enter the fish supply chain either primarily from human or animal faeces but also secondarily from contaminated water sources.

The genus *Enterococcus* was carved out of the earlier larger genus, Streptococcus, and 'faecal *streptococci*' or 'Lancefield's group D s*treptococci'* are still maintained in this genus. Out of the 20 species of this genus, only two (*E. faecalis* and *E. faecium*) are suggested to be responsible for nosocomial infections. The *Enterococcus* spp. is regular Gram-positive, non-spore-forming, non-motile, facultative anaerobic, gamma-haemolytic on blood agar, catalase negative, homofermentative ovoid cocci (pairs to short chains). These bacteria can grow between temperature ranges of 5 to 50°C with an optimum growth temperature of 30 to 37°C. Typical pH ranges for growth is 4.6 to 9.9 with an optimum growth pH at neutral condition i.e. at 6.0-7.0.

Detection of Enterococci are defined as the organisms that produce pink to red colonies with a black or reddish-brown precipitate after primary culture for 48 to 50 hours at 41.0 ± 0.5°C on m-Eenterococcus medium followed by incubation for 20 minutes at 41.0°C on Eusculin Iron Agar medium (EIA medium).

4. Sulphite-reducing clostridia and other anaerobes: Until bifidobacteria were suggested as faecal indicators by Mossel, 1958. *C. perfringens* was the only obligately anaerobic, enteric micro-organism seriously considered as a possible indicator of the sanitary quality of water. Anaerobic sulphite-reducing clostridia are much less prevalent than bifidobacteria in human faeces. But their spore-forming habit gives them high environmental resistance (Cabelli, 1978). *C. perfringens* is the species of clostridia most often associated with the faeces of warm-blooded animals (Rosebury 1962), but is only present in 13–35% of human faeces. Although *C. perfringens* has been considered a useful indicator species for more than a hundred years (Klein and Houston 1899). Perfringens as a faecal indicator and could present in the environment for a long duration, which is considered to be significantly longer than enteric pathogens (Cabelli, 1978). Bonde (1963) suggested that all SRC in receiving waters are not indicators of faecal pollution, hence *C. perfringens* is the appropriate indicator.

5. Bacteriophages: Viruses that infect bacteria, first described from the intestinal tract of man in the early 1900s. Use of phages as models for indicating the likely presence of pathogenic enteric bacteria first appeared in the 1930s. Direct correlations exists between the presence of certain bacteriophages and the intensity of faecal contamination.The evolving role for phages to coliforms, known as coliphages-model human enteric viruses.

Major groups of indicator coliphages (Leelere et al., 2000)

Family	Phage examples
Myoviridae	T2, T4, T6
Siphoviridae	λ, T5
Podoviridae	T7, T3
Microviridae	ϕX174, S13
Inoviridae	SJ2, fd, AF-2, M13

7. **Yeasts and Moulds:** Yeasts and moulds are commonly enumerated in foods as quality indicators. No predictive value for the occurrence of toxigenic/ pathogenic fungi. Yeasts and moulds are diverse and can grow on any type of food. It can survive in a wide range of environmental conditions: pH 2–9; temperatures of 5º–35^{0}C; and water activity (a_w) of 0.85 or less. As quality indicators, used to assess acceptability, organoleptic characteristics, stability, and shelf life of a product.

Detection and enumeration: Yeasts and moulds are enumerated by a plate count procedure that uses agar supplemented with agents inhibitory to bacteria. Chloramphenicol, rose bengal, and dichloran are common selective agents. Spread or pour plates, incubated at 25ºC for 3–7 days, are recommended (ISO 7954). Rapid official methods using HGMF (AOAC 995.21) and dry rehydratable film (AOAC 997.02) recommend 50 hours or 5-day incubation, respectively. A method using the SimPlate colorimetric format determines yeast and mould counts in 56–72 hours (AOAC 2002.11). There is a need for more research to improve methods for determining yeasts and moulds in foods.

Emerging Microbiological Methods for the Detection of Hygienic Indicators Bacteria

Fast detections using chromogenic substances: Chromogenic substances are modified either by enzymes (bacteria) or by specific bacterial metabolites. Chromogenic substance changes theircolour or fluorescence, easy detection of those colonies, avoids the need for isolation of pure cultures and confirmatory tests. The time required for the determination of different indicator bacteria can be reduced between 14 to 18 hours. For example Extended-spectrum of Beta Lactamase producing *E. coli* (ESBL) and *E. coli* O 157.

Application of monoclonal and polyclonal antibodies: Mab has been successfully used for the detection of indicator bacteria in water samples (Hübner *et al.* 1992; Obst *et al.* 1994). Detection of 'viable' indicators is the combination of immunofluorescence with a respiratory activity compound. Detection of *E. coli O157:H7, S. typhimurium* and *K.pneumoniae in water* (Pyle *et al.* 1995). Antibody technology is often used in medicine with enzyme amplification (ELISA).

IMS/culture and rapid culture-based methods: Immunomagnetic separation offers an alternative approach to rapid identification of culturable and non-culturable micro-organisms (Safarik *et al.* 1995). Principles and application of the method are based on suitable antibody specificity. Purified antigens are typically biotinylated and bound to streptoavidin-coated paramagnetic particles. The raw sample is gently mixed with the immunomagnetic beads, then a specific magnet is used to hold the target organisms against the wall of the recovery vial, and non-bound material is poured off. Target organisms can then be cultured or identified by direct means. IMS approach may be applied to the recovery of indicator bacteria from water but is possibly more suited to replace labour-intensive methods for specific pathogens. Recovery of *E. coli* O157 from water (Anon, 1996).

Quantitative Polymerase Chain Reaction (qPCR) is a rapid, culture-independent method to detect the actual number of indicator bacteria in the fish products. It is a novel primer-based molecular technique for the quantification of the presence of specific types of nucleic acid in seafood and aquaculture products. With this qPCR could quantify simultaneously 2- 3 indicator bacteria of *E. coli* , Enterococcus sp and fecal streptococci using the target of either 16SrRNA or 16SrDNA directly from the sample. With qPCR could able to detect a lower limit of detection of 1-10 *E. coli*/100ml and 10-100 E. faecalis/100ml.

Gene sequence-based methods: Based on the recognition of specific gene sequences. Usually rapid and can be tailored to detect specific strains of organisms. PCR (polymerase chain reaction), FISH (fluorescence in-situ hybridisation), use gene probes with a fluorescent marker, typically targeting the 16S ribosomal RNA (16S rRNA).

LIMITATIONS IN DETECTIONG INDICATOR BACTERIA

- Some of the indicator bacteria are environmental origins i.e. environmental reservoirs
- Some of the indicator bacteria are both fecal and non-fecal origin
- Some of the tests for fecal indicator may also detect non-fecal microbes.
- monitoring programs are typically conducted using culture-based methods that require an 18 to 96 hour incubation period

FUTURE DEVELOPMENTS:

- Microarrays and biosensors
- Biosensors based on antibody technology, with the antigen triggering a transducer or linking to an enzyme amplification system.
- Microarrays using DNA/RNA probe-based rRNA targets may be coupled to adjacent detectors.

- Rapid QPCR methods
- Whole Genome Sequencing & metagenomics approach

CURRENT APPLICABILITY OF FAECAL INDICATORS

- Members of the total coliform group and faecal coliforms
- *E. coli* is considered as the main source of recent faecal contamination and is now considered to be *E. coli* and enterococci.
- *Clostridium perfringens* is considered as an alternative indicator to *E. coli* and enterococci.

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30. Antimicrobial Resistance (AMR) in Aquatic products

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i. *Role of aquaculture in global fisheries:*

Aquaculture i.e. the rearing of fish in freshwater, brackish water or marine water under controlled conditions, is increasingly contributing to the world's fish production. The contribution of aquaculture to global fish production increased from 25.7% in 2000 to 46% in 2018. The term 'fish' used in this context includes fin-fish, crustaceans, molluscs and other aquatic animals but excludes aquatic mammals, reptiles, seaweeds and other aquatic plants. Globally in 2018, aquaculture contributed 82 million tonnes out of the total 179 million tonnes of fish production (FAO, 2020). Within aquaculture, inland aquaculture that is practiced in the land based freshwater and brackish water aquatic bodies contributed 51.3 million tonnes (63%) and the mariculture practiced in open seas contributed 30.8 million tonnes (37%). Value-wise aquaculture production was valued at USD 250 billion. Region-wise, Asia (69%) dominates the aquaculture production followed by the Americas (14%), Europe (10%), Africa (7%) and Oceania (1%). The top five aquaculture producing countries in the world in 2018 were China (57.93%), India (8.61%), Indonesia (6.61%), Viet Nam (5.04%) and Bangladesh (2.93%). Moreover, aquaculture production constituted more than 50% of the country's total fish production in China (76.5%), India (57%), Viet Nam (55.3%) and Bangladesh (56.2%). In the last two decades, world aquaculture was dominated by Asia while Africa and the Americas improved their share but Europe and Oceania have dropped slightly. Fish-group wise, aquaculture was dominated by fin-fish (54.3 million tonnes), mollusc (17.7 million tonnes) and crustaceans (9.4 million tonnes). Shrimps, salmon, bivalves, tilapia, carps, catfish (including Pangasius spp.) were the main groups farmed worldwide.

ii. *Role of fish in human diet:*

Worldwide consumers relish fish as food, owing to its nutritional and health benefits. The richness in omega-3 polyunsaturated fatty acids (EPA, DHA), good quality protein, important minerals (iron, calcium, zinc, selenium) and vitamins (A, B, D) makes fish meat a nutritious and healthy food item. Fish meat consumption is associated with several health benefits such as reduced coronary diseases, improved neurodevelopment in children and better cognitive function in the elderly. Seventeen percent of the global animal protein intake and seven percent of all protein consumed was contributed by fisheries. The per capita consumption of fish increased from 9 kg in 1961 to 20.5 kg in 2018. Increase in the awareness on the health benefits of fish coupled with better purchasing power of people is expected to further drive the demand for fish as food. Globally, aquaculture has been increasingly providing fish for human consumption. In 1950 aquaculture provided only 4% of the fish meant for human consumption, which increased to 9% in 1980, 19% in 1990, 52% in 2018 (FAO, 2020) and is expected to provide 59% of the fish by 2030.

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iii. Antimicrobial resistance

Antimicrobial resistance (AMR) is the non-responsiveness of microorganisms to antimicrobial agents in standard doses making it difficult to treat an infectious disease. Emergence of antibiotic resistance in bacterial pathogens is recognized as a major public health threat affecting humans worldwide and World Health Organisation has named antibiotic resistance as one of the three most important public health threats of the 21st century. AMR can affect anyone, of any age, in any country and is a threat to food security and sustainable development. Globally, AMR is responsible for 700,000 deaths annually and is predicted that AMR might cause 10 million deaths per year by 2050. Economy-wise AMR might cause USD 100 trillion loss and 3.5% reduction in GDP by 2050.

Antimicrobials are vital for the treatment of bacterial infections in humans, terrestrial animals and aquatic animals. Antibiotics exert their antibacterial action by several mechanisms such as inhibiting the bacterial cell wall synthesis (penicillins, cephalosporins, monobactams, carbapenems), disrupting the bacterial cell membrane (polymyxin, colistin, daptomycin), inhibiting protein synthesis (phenicols, macrolides, tetracyclines) or inhibiting nucleic acid synthesis or replication (sulfonamides, trimethoprim, quinolones, fluroquinolones). More and more species of bacteria are becoming resistant to existing antibiotics. Magiorakos et al. (2012) has defined multidrug resistant bacteria (MDR) as a strain that had acquired resistance to at least one agent in three or more antimicrobial classes. Extremely drug resistant (XDR), and total drug resistant (TDR) superbugs are emerging due to multiple mutations which have the brutal power to enhance morbidity and mortality. There is lack of interest by the pharmaceutical companies to develop new antibiotics as the bacteria were becoming rapidly resistant to newly introduced antibiotics, thus making the business less profitable. The mean duration of resistance was reported to be 6.9 years (Nelson *et al*., 2019).

Antibiotic resistance in bacterium is classified as intrinsic resistance and acquired resistance. Intrinsic resistance refers to the natural existence of genes in the bacteria that make the bacteria resistant to that particular antibiotic. For example, resistance to penicillin is expressed by most Gram-negative bacteria. *Aeromonas* spp., commonly found in freshwater aquaculture environments, have been reported to have intrinsic resistance to ampicillin. In clinical settings, the resistance is usually ‘acquired’, wherein the bacterial population that was originally susceptible to an antibiotic acquires resistance. Acquired antibiotic resistance results, either from mutations in the chromosomal gene (vertical transmission) or due to acquisition of resistance genes from other bacteria in the environment (horizontal gene transfer, HGT). Horizontal gene transfer occurs through uptake of free DNA by a competent bacterial cell (transformation) or by mobilization of bacterial DNA from one bacterial cell to another by a bacteriophage (transduction) or by mobilization of DNA from a donor bacterium to a recipient bacterium through conjugative machinery (conjugation). HGT is the most relevant mode of resistance emergence and spread in bacterial populations.

Bacteria develop resistance to antibiotics by adopting different strategies such as modifying the antimicrobial molecule, preventing the antibiotic from reaching the target site, changing the antibiotic target sites and bypassing the antibiotic target sites (Murugadas *et al*., 2019).

a) *Altering the antibiotic:* Bacteria produce enzymes such as acetyltransferase, phosphotransferase, adenyltransferase, that introduce chemical changes in the antibiotic molecule and modify them leading to loss of their antimicrobial property. This type of resistance was reported towards chloramphenicol, aminoglycosides and lincosamides

b) *Destroying the antibiotic:* Bacteria produce enzymes such as β-lactamases, Extended Spectrum β-Lactamases, that completely destroy the antibiotic making it incapable of executing its antibacterial function. This type of resistance was reported against penicillins, cephalosporins and monobactams,

c) *Target protection:* Bacteria alter the ribosomal conformation. This type of resistance was reported towards tetracycline, fluoroquinolones and fusidic acid.

d) *Target modification:* Bacteria modify the target site and decrease the affinity of the antibiotic for the target site. This type of resistance was reported against fluoroquinolone, rifampin and erythromycin

e) *Decrease permeability to prevent antibiotic entry:* Bacteria develop mechanisms to prevent the antibiotic from reaching its intracellular or periplasmic target. This mechanism limits the influx of substances from the external environment. This type of resistance was reported towards β-lactams, tetracyclines and some fluoroquinolones

f) *Efflux Pumps to flush out antibiotics from the bacterial cell:* Efflux pumps are transport proteins involved in the extrusion of toxic substrates. Efflux pumps have been characterized in both Gram-negative and Gram-positive bacteria. This type of resistance was reported against fluoroquinolones, β-lactams, carbapenems and polymyxins.

iv. ***Detection of antimicrobial resistance***

AMR is detected phenotypically by employing the disk diffusion assay (qualitative) or by determining the minimum inhibitory concentration (quantitative). Genotypic methods are used to detect the antibiotic resistance genes either by conventional PCR (qualitative) or real time PCR (quantitative). Disk diffusion assay is performed as per Kirby-Bauer method by placing six discs of selected antibiotics on Mueller-Hinton agar plates seeded with the target bacterium (1.5 x 10^8 cfu/ml). The inhibition zone size is measured and the results are interpreted as per internationally recognized guidelines such as Clinical and Laboratory Standards Institute (CLSI) and European Committee on Antimicrobial susceptibility testing (EUCAT). The minimum inhibitory concentration (MIC) method determines the lowest concentration of an antibiotic that inhibits the growth of the target bacterial isolate. MIC test can be performed either by liquid broth dilution methods (tube dilution, microbroth dilution) or solid agar dilution methods. The preferred method is the microbroth dilution method in 96 well plates using cation adjusted Mueller-Hinton broth and using the target bacterium at an inoculum level of 5 x 10^5 cfu/ml. E-test (epsilometer test) is also a quantitative method that uses an inert strip with a pre-defined gradient of specific antibiotic that is placed on a Mueller-Hinton agar plate seeded with the target bacteria. The MIC is derived from the symmetrical inhibition ellipse that is seen after the incubation period. It is necessary to regularly employ quality control strains to evaluate the performance of the antibiotic susceptibility test method in the laboratory as several factors such as media composition, inoculum size, quality of antibiotic discs, incubation temperature etc., severely affect the test results. The commonly used quality control strains were *E.coli* ATCC25922, *Pseudomonas aeruginosa* ATCC27853, *Staphylococcus aureus* ATCC25923 and *Streptococcus pneumoniae* ATCC49619. Interpretative criteria can be of two types viz., clinical breakpoints or epidemiological cut-off values. Clinical breakpoints categorize a bacterial isolate as either sensitive (S), intermediate (I) or resistant (R) and indicate the most probable outcome of specific therapy of a specified infected host. 'Sensitive' indicates that using that particular antibiotic would be helpful in treating the infection whereas 'resistant' suggests that the clinical outcome of using that specific antibiotic would not have a positive therapeutic outcome. On the other hand, epidemiological cut-off values categorize bacterial isolates as wild type (fully susceptible) or non-wild type (reduced susceptibility) when compared to other members of its species. Advanced tools such as antibiotic resistance gene detection chips, microarray expression analysis, transcriptomics, metatranscriptomics, functional metagenomics, next-generation sequencing, single molecule real-time sequencing methods were also used for diagnostics and AMR deciphering. The test procedures and interpretation guidelines for human pathogenic bacteria are relatively well established but analysing antimicrobial resistance in bacteria isolated from aquatic animals presents certain difficulties in terms of laboratory procedures and interpretation guidelines (Smith, 2019). Human bacterial pathogens are isolated at 35±2ºC whereas bacterial pathogens of aquatic animals are generally isolated at 28±2ºC (tropical regions) or 22±2ºC (temperate regions). Limited clinical breakpoints relevant for the treatment of aquatic animals have been provided by CLSI.

v. ***Surveillance of AMR:***

Integrated surveillance of AMR in food-producing animals, foods, and humans globally with standardised approaches and timely sharing of data is key to identifying potential routes and sources of transmission. Surveillance laboratories currently use culture and PCR-based methods to determine the antibiotic resistant bacteria (ARB) and antibiotic resistance gene (ARG) profiles of pathogenic bacteria. Global Antimicrobial Resistance Surveillance System (GLASS) undertakes surveillance at global scale. The Indian Network for Fisheries and Animal Antimicrobial Resistance (INFAAR), established in 2018, is a network of laboratories for AMR surveillance in the terrestrial animals and fisheries sector in India. The network is a step in the direction to fulfil India's obligation towards Global Action Plan (GAP) on AMR and Nation Action Plan (NAP) on AMR.

vi. ***Antimicrobial use in aquaculture:***

Bacterial diseases in freshwater fish (Eg. *Aeromoniasis*, *Edwardsiellosis* etc) and shell-fish (Eg. *Vibriosis*) are a major constraint that hamper aquaculture production in Asia. The larval and juvenile stages of aquatic animals are usually more susceptible to bacterial infections.

Mortalities in younger populations may reach up to 35-40% whereas in older populations the mortality rate were around 15-25%. Gram-negative and Gram-positive bacteria have been associated with infections in aquatic animals in the temperate and tropical regions. The antibiotics are usually administered by mixing with feed on the farm premises. In some countries, ready-to-use feeds premixed with antibiotics are also available.

Table 1. Bacteria associated with infections in farmed aquatic animals

Gram-negative bacteria	
Non-fastidious	*Aeromonas caviae, Aeromonas hydrophila, Aeromonas jandaei, Aeromonas salmonicida, Aeromonas sobria, Aeromonas veronii, Acinetobacter spp., Citrobacter freundi, Edwardsiella anguillarum, Edwardsiella ictalurid, Edwardsiella piscicida, Edwardsiella tarda, Pseudomonas anguilliseptica, Pseudomonas fluorescens, Yersinia ruckeri*
Facultative and obligate halophiles	*Vibrio alginolyticus, Vibrio parahaemolyticus Vibrio harveyi, Vibrio vulnificus, Vibrio anguillarum, Photobacterium damselae, Aliivibrio salmonicida*
Flavobacteria and related species	*Flavobacterium columnare, Flavobacterium branchiophilum, Flavobacterium psychrophilum, Tenacibaculum maritimum*
Gram-positive bacteria	
Mesophilic cocci	*Lactococcus garvieae, Streptococcus iniae Streptococcus agalactiae, Streptococcus dysgalactia, Streptococcus phocae*
	Aerococcus viridans, Weissella spp.
Psychrophilic cocci	*Lactococcus piscium, Vagococcus salmoninarum*
Mycobacteria and related species	*Mycobacterium marinum, Mycobacterium fortuitum Nocardia crassostreae, Nocardia seriolae, Nocardia asteroides*

Unlike in human and veterinary health care, there are no antibiotics specifically developed for use in aquaculture (FAO, 2017). Sulphonamides potentiated with trimethoprim were the first antibiotics used in fish farming in 1970s. Global consumption of antimicrobials in aquaculture was 10,259 tonnes in 2017 and it is projected to reach 236,757 tonnes in 2030 (Schar *et al*., 2020). The share of antimicrobial use in 2030 is expected to be the lowest in aquatic animal (5.7%) followed by human use (20.5%) and terrestrial animal use (73.7%). Fish-species wise consumption of antibiotics was estimated to be higher in catfish (157mg/kg) followed by trout (103 mg/kg), tilapia (59 mg/kg), shrimp (46mg/kg) and salmon (27mg/kg) farming. The quantity and the class of antibiotics used in aquaculture vary with the countries. In salmon fish farming, the quantity of antibiotic used per ton of fish production varied from 0.02-1.3g in Norway to 660-700g in Chile (Watts *et al*., 2017). The most commonly used classes of antibiotics in global aquaculture were quinolones, tetracyclines, amphenicols and sulfonamides. The important antimicrobial agents for treatment of fish mentioned in the list of antimicrobial agents of veterinary importance by the World Organisation of Animal Health (OIE) is given in Table 2.

Table 2. World organisation of Animal Health (OIE) list of antimicrobial agents for use in fish for treatment purpose

Category	Antibiotic Class	Antibiotics
Veterinary critically important antimicrobial agents (VCIA)	Tetracyclines	Doxycycline, Oxytetracycline, Tetracycline
	Sulfonamides	Sulfafurazole, Sulfamethoxine, Sulfamonomethoxine, Trimethoprim-Sulfonamide
	Quinalones	Flumequine, Oxolinic acid, Enrofloxacin
	Phenicols	Florfenicol, Thiamphenicol
	Aminopenicillins	Amoxicillin, Ampicillin
	Carboxypenicillins	Tobicillin
	Bicyclomycin	Bicozamycin
	Macrolides	Erythromycin, Spiramycin
	Aminoglyocisides	Spectinomycin, Streptomycin, Kanamycin
Veterinary highly important antimicrobial agents (VHIA)	Fosfomycin	Fosfomycin
	Lincosamides	Lincomycin
Veterinary important antimicrobial agents (VIA)	Aminocoumarin	Novobiocin

** OIE list of antimicrobial agents of veterinary importance, adopted by the OIE International Committee at its 75th General Session in 2007 (Resolution No. XXVIII) and updated in 2013, 2015 and 2018 by the World Assembly of OIE Delegates.*

The antibiotics approved for use in aquaculture in the United States were florfenicol, oxytetracycline and sulfadimethoxine/ormetoprim and the antibiotics commonly used in aquaculture in Europe were florfenicol, oxolinic acid and flumequine. In Asia, the commonly used antibiotics in aquaculture include amoxicillin, erythromycin, florfenicol, oxytetracycline, chlortetracycline, tetracycline, doxycycline, sulfadimethoxine/ ormethoprim and sulfadimethoxine/ trimethoprim. However, the diversity of the aquatic animals i.e. fin-fish, crustaceans, mollusks which are farmed in different aquatic environment such as freshwater, brackish water, marine waters makes it difficult to prescribe antibiotics for aquatic animal health management.

vii. **Antimicrobial resistance (AMR) in aquaculture:**

Aquaculture environment is perceived as hotspot for AMR where genetic exchange and recombination leads to emergence, persistence and transmission of resistance at a relatively higher frequency. Unscientific farming of fish and shrimp with weak biosecurity measures and irresponsible animal health management practices has led to the increase in disease incidence in fin-fish and shell fish aquaculture. Unlike in human health care and terrestrial animal health care, it is generally not possible to treat individual fish and shrimp in aquaculture farms and hence the application of antibiotics is done by adopting a metaphylactic approach, where both the infected and healthy aquatic animals are exposed to the antibiotic. The inappropriate use of antibiotics in aquaculture leads to the emergence of AMR in bacteria in the aquatic environment. The emergence of drug resistance in fish pathogens makes it difficult to control diseases in aquaculture leading to crop failures and economic loss to the farmers. Infections in aquatic animals due to antibiotic resistant bacteria were reported in shrimp (Karunasagar *et al*., 1994) and fin-fish (FAO/OIE/WHO, 2006). Moreover, the spread of AMR from bacteria in the aquatic environment to bacteria of public health significance poses serious consequences to the human health care.

The enzymes / proteins involved in the antibiotic resistance are encoded by several antibiotic resistance genes (ARGs). The aquatic environments also act as reservoirs of AMR genes that can be potentially transferred to human pathogens. The bacteria in the aquaculture environment receive the ARGs, mainly through horizontal gene transfer from other bacteria that enter into the aquatic environment. Transfer of ARGs is restricted neither by phylogentic differences among bacteria nor by sectoral boundaries such as human sector and terrestrial animals. The ARGs reported in bacteria associated with aquaculture include *gyrA, gyrB, parC, pare, qnrB, qnrS* genes responsible for quinolone resistance; *tetA, tetB, tetD, tetE, tetG, tetH, tetL, tetM, tetO, tetQ, tetS, tetW, tet34,* and *tet35* associated with tetracycline resistance; *sul2* associated with sulfonamide resistance; *strA–strB* associated with streptomycin resistance and *floR* responsible for florfenicol resistance. Data on the prevalence of ARGs in the aquaculture environment is pertinent for quantitative risk assessments and control of fish diseases. Research thrust is needed to decipher the resistome (collection of all ARGs in a bacterial community) of different aquaculture habitats *viz*., freshwater aquaculture, brackish water aquaculture to understand the emergence and spread of AMR in the specific habitats.

a) AMR in culture fisheries: Bacteria gain entry into the aquaculture pond during the culture phase through several sources and some of the bacteria may possibly be AMR strains (Rao *et* *al*., 2021).

- Fish seed (fish fry/ shrimp post-larvae) carry bacteria from the hatcheries. The AMR bacterial strains present on the fish seed may be carried along with the animals from the hatchery environment to the aquaculture farms.

- Manure from poultry and livestock is used in fish farms to promote phytoplankton growth. Manure is also a source of AMR bacteria in to the aquaculture farms.

- Water exchange is common in aquaculture practice wherein water from open canals/creeks is pumped regularly in to the pond. Water meshes used for screening water before pumping into the pond do not prevent the entry of bacteria into the fish ponds.

- The pond sediment contains ten times higher bacterial loads compared to the water column. The soil particles act as an interface for microbial community interactions including transfer of antibiotic resistance.

- Beneficial bacteria in the form of probiotics are added to the aquaculture ponds for improving the health status of the aquatic animal (gut probiotics) or improving the water quality (water remediators) and soil quality (soil remediators) for the growth of the farmed aquatic animals. Generally, probiotics contain more than billion bacteria per gram and addition of probiotics at regular intervals adds large populations of bacteria. It was reported that some of the probiotics carry AMR genes and transfer them to other bacteria in the gut or aquatic environment (Verraes *et al*., 2013).

- Feed and feed supplements used regularly during the growing stage of the fish contain relatively low number of bacteria but nevertheless add microorganisms into the system.

- Poor biosecurity measures allow the entry of birds and crabs into the ponds and these may transfer bacteria between fish ponds.

- Farm personnel/ fishermen enter the pond regularly for pond management and the time of fish harvest. Unhygienic habits of the personnel and improperly santizied fishing gear introduce bacteria into the pond water.

- The presence of heavy metals in the aquatic environment co-select AMR bacteria.

- The use of antimicrobials for disease control leads to the emergence and dissemination of AMR strains in the pond environment.

- Some of the bacteria introduced through these channels may be already resistant to antibiotics (AMR strains) or may develop resistance within the pond environment. Antibiotic resistance was reported in *Aeromonas, Pseudomonas, Salmonella* and *Vibrio* in fish collected from fish farms and the aquatic environment. Resistance was reported in bacteria isolated from fish ponds towards ampicillin, amoxicillin, carbenicillin, cephalexin, cephalothin, colistin, erythromycin, gentamicin, kanamycin, novobiocin, penicillin-G, rifampin, sulfadiazine, tetracycline and vancomycin.

b) **AMR in post-harvest fisheries:** The AMR bacteria from the harvested fish, either from capture fisheries or culture fisheries, is transmitted to humans through the consumption of contaminated food, contact with the aquatic animals and /or environmental contamination (Wohde *et al*., 2016). However, bacteria including AMR resistance strains gain entry on to the harvested fish through contaminated water used in fish processing/cleaning, contaminated ice used for preserving/storing the fish and unclean food contact surfaces used for display of fish. Harvested fish come in contact with different food contact surfaces such as crates, weighing scales, utensils, pre-processing and processing tables, freezing pans, conveyor belts etc. Improperly washed food contact surfaces carry high counts of bacteria. The unhygienic practices of food handlers during raw material handling, pre-processing, processing, transport and sale of fish are possible source of entry of AMR bacteria.

c) Steps to mitigate AMR in pre-harvest and post-harvest fisheries: Mitigation measures needs to be followed in both the pre-harvest and post-harvest stages by all the stakeholders to mitigate antimicrobial resistance in bacteria in the fisheries sector (Rao *et al*., 2021).

- Farmers and hatchery operators should compulsorily adopt scientific farming and follow good aquaculture practices to prevent infections. All the farms and hatcheries need to be registered and maintain records of all the inputs used during the rearing period.
- Specific pathogen free (SPF) or specific pathogen resistant (SPR) and healthy broodstock should be used in hatcheries. Only disease free and active fish-fry/ shrimp post-larvae have to be supplied to the farmers.
- Aquaculture farmers should stock the fish seed at appropriate stocking densities with proper water management and feed management to avoid build up of unwanted bacteria.
- The feed and feed supplements used in aquaculture should be invariably tested for the presence of antibiotics by the manufacturers and clearly labeled as ‘free from antibiotics’ on the packs. The feed and feed supplement manufactures must ensure that the ingredients used in product manufacture are free from antibiotics.
- Non-AMR probiotic strains have to be employed for water quality management, improving sediment condition and improving the health of animals
- All aquaculture farms should have better biosecurity measures such as bird nets, crab fencing, vehicle disinfection, hand sanitization facilities on the farm to prevent entry of bacteria from external sources.
- Awareness on personal hygiene and AMR needs to be created among the fish harvesters. Measures such as bathing before entering into the pond water and after

coming out, using hand dips before handling aquatic animals should be strictly followed to prevent transmission of bacteria from humans to animals and vice versa.

- Fishermen should disinfect their fishing gear in potassium permanganate solution to reduce external introduction of bacteria and prevent the transfer of bacteria between different fish ponds.
- Antibiotic stewardship needs to be advocated among fish health professionals for controlling fish diseases (correct diagnosis, use of permitted antibiotics based on antibiotic treatment based on antibiotic susceptibility test results; rotation in use of approved antibiotics etc.)
- There is a need for development of rapid on-site diagnostic tests to prevent inappropriate use of antibiotics such as using antibiotics for treating viral infections.
- Research needs to be undertaken to develop alternatives to antibiotics such as vaccines, bacteriophages, bacteriocins, probiotics, quorum sensing inhibitors etc., for disease prevention and control in aquatic animals. The dose and treatment period of the developed antimicrobials also needs to be standardized.
- Strict enforcement of drug regulation to control the accessibility of antibiotics to the aquaculture farmers and hatchery operators.
- Prevent bacterial contamination during harvesting, processing, marketing and transport of fish. Use only potable water for processing of fish, good quality ice for maintaining chilled condition and maintain cleanliness and safety of all food contact surfaces.
- Surveillance on AMU and AMR fisheries needs to be strengthened to make a realistic assessment of the risk that AMR in fisheries poses to the human population.

viii. ***One Health approach for addressing AMR:***

AMR is an issue that needs to be addressed globally with a multisectoral approach. The 'One health' is a concept which acknowledges that human health is interconnected with animals, agriculture and environment. Therefore, AMR containment requires close collaboration between human, veterinary health and environment. Global Action Plan (GAP) on Antimicrobial Resistance was developed by the World Health Organization (WHO) in coordination with the Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE).

Collective efforts of aquaculture farmers, hatchery operators, feed manufacturers, fishermen, fish processors, fish retailers, ice manufacturers, drug manufacturers, fish laboratories, food regulatory agencies, veterinarians, researchers and policy maker public is needed to fight the challenges of antimicrobial resistance in the fisheries sector.

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31. Designing Food Safety Management System

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Food provides the basic requirements of growth and sustenance of life. It goes beyond saying that whatever is being consumed should be good and safe to the consumers. The concept is important not only from the individual point of view but across the globe as food is an important health, social and economic issue. The abuse of safety leads to incidence of food borne illness and it is estimated that food and waterborne diseases kill 2.2 million people annually and about 87% of this are children (WHO, 2002). From the point of consumer health protection, world organisations are taking collective steps and the training material from the WHO bearing title "Five Keys to safer food" assumes significance in reducing the burden of food-borne diseases.

Most important issues come from the question that who is responsible for food safety. Obviously, each and every player concerned with all activities are responsible for safety of the consumer. Over the years systems are developed or being developed continuously with the aim of consumer protection. Food safety means that food will not harm the consumer if consumed in the recommended way (CAC, 2017). Food safety is also referring to the absence of hazards entering the system at any stage of processing and causing foodborne illness (Jevsnik et al., 2008). Therefore, the food safety system should be designed to control the food production process based on the available prevention principles and understanding. The food safety producers have to implement the food safety management system to ensure safety of the food to the expectations of the consumers. The world food summit in 2002, view this as the right of everyone to have access to nutritious and safe food making every effort to establish, implement and upgrade the food safety and quality control systems everywhere (Kondakci & Zhou, 2017).

It is clearly demonstrated world over that the food borne illness are the consequence of unhealthy and unhygienic food production environment which have direct impact on the quality of food. This not only impact the consumers health but also economic consequences (Matthews, 2013). In the context of global market reach, the requirement of systematically managed safety in food supply chains is strong and has been staunchly followed in the regulatory framework. Besides, the regulatory measures are given priority and often harmonised to the requirements of international consumers as well, signifying the importance of food safety.

The concept of food safety and the consequences of unsafe food are well understood by the consumers today and their expectations from the food industries are high with respect to quality, diversified products, safe certificates etc. while looking for a food. This is the primary driving force for the food industries to go for improved quality standards by adopting the better food safety standard systems (FSMS) in the production systems and to focus on safety, quality, efficiency, reliability and environmentally friendly as well as economic products and packaging (Wentholt et al., 2009; Al-Busaidi et al., 2017).

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As per the guidelines of Codex Alimentarius Commission the food meant for consumption shall provide guarantee of its safety to the consumers and it becomes the necessity of the producers to prevent the incidence of hazards at any point from "farm to fork" or from any other system.

In order to provide the basic understanding on this very principle, the International Organization for Standardization (ISO) provided the requirements of a food safety management system and reiterates that it is the responsibility of the organisation concerned to control and coordinate by setting quality objectives and implementation of quality policy for food quality assurance with a system of continuous improvement.

What is Food Safety Management System?

Food Safety Management System (FSMS) is a written document which discusses the details of managing food safety and hygiene in a production system. The system has its own risk profile and is also under the governance of regulatory provisions and therefore the FSMS shall detail the procedures used to maintain compliance by indicating hazards and risks specific to the system and their control and other relevant information necessary to manage the food safety successfully. The established global standard ISO 22000:2005 was used extensively since its release in 2005 and has undergone revisions and updates over the year to accommodate the changes (Table 1).

Table 1 Chronology of developmental old FSMS

FSMS	Scope	Year of Implementation
ISO 22000: 2005 FSMS: Requirements for organization in food sector	Ensuring the absence of feeble links in food chain	2005
ISO/TS 22002-1:2009: PRP on food safety-part 1: Food manufacturing	Technical specifications specify requirements for establishing, implementing, and maintaining PRPs to assist in controlling food safety hazards	2009
ISO/TS 22003:2007: FSMS—Requirements for bodies providing audit and certification of FSMS	Technical specifications define the applicable rules for the audit of a FSMS and offer synchronized guidance for accreditation of certification bodies compliant with ISO 22000	2007
ISO/TS 22004:2005 FSMS-Guidance on the application of ISO 22000:205	Providing guidelines for implementation of ISO 22000 for food safety	2005
ISO 2005:2007: Traceability in the feed and food chain: General principles and basic requirements for system	Standard gives the principles and specify the basic requirements for the design and implementation of a feed and food traceability system	2007

design and implementation		
ISO/TS 22002-3:2011 Specific prerequisites for farming		2011
ISO/TS 22002-6:2016 PRP on food safety Part 6: Feed production	Providing guidelines for implementation of ISO 22000 in feed production	2016

The ISO incorporated the principles of Hazard Analysis and Critical Control Point (HACCP) and pre requisite programmes in to the ISO 22000 quality management system in 2005 and the standard includes rules, definitions, or test procedures of different characteristics and technical specifications (Raspor & Ambrozic, 2012).

The standard can be implemented by anybody connected with food chain business directly or indirectly. ISO 22000 includes all standards that reinforce implementation of this system in trustworthy and professional manner. The food chain covers all steps of production and manufacturing operations including consumption of processed and unprocessed food products. There are also instances that food chain includes organizations that are not directly involved with food processing but with production of ingredients or certain raw materials which also come under the purview of food production system (Jung, Jang, & Matthews, 2014). The ultimate objective of ISO 22000 is to deliver safe and quality food to the consumer. The ISO 22000:2005 has clauses discussing the FSMS requirements followed by management requirements, Pre-requisite programmes for hazard control and verification, hazard analysis, validation, verification and documentation (Table 2). The standard also provides a sort of comparison between ISO 22000:2005 and ISO 9001:2005, comparison between HACCP and ISO 22000:2005 as well as examples of control measures and PRPs and the selection of appropriate control measures. ISO 22000 helps to plan, establish, and implement FSMS for an organization. The ultimate principle of food safety is to control the hazards with a view to protect consumer health.

Table 2 Clause-wise description of ISO 22000

Clause		Description
1	Scope	Defines the scope of ISO 22000 and identifies certain limitations and exclusions.
2	Normative references	Refers to other publications that provide information or guidance
3	Terms and definitions	Identification and definition of key terms that are of fundamental importance for FSMA and for using ISO 22000
4	FSMS	It discusses about the general requirements, documentation requirements for ISO 22000 Standards.

5	Management responsibility	It discusses about the management responsibility, food safety policy, responsibility and authority, food safety team leader, communication, and management review
6	Resource management	It details out the human resources, competence, awareness and training, infrastructure, and work environment
7	Planning and realization of safe products	It describes the PRPs, preliminary steps to enable hazard analysis, product characteristics, flow diagrams, process steps and control measures, hazard analysis, establishment of OPRP, HACCP plan, verification plan and traceability, control of nonconformity.
8	Validation, verification, and improvement of FSMS	It discusses about validation, verification, and improvement of FSMS

The regulatory and statutory requirements applicable to food safety in an organization are focused through food safety management system. Capacity building in the area of food safety with specific reference to trade related requirements along the different stages of the production, procurement, processing and distribution is an important element of the FSMS system (Matthews et al., 2014), besides minimising food safety hazards in order to provide safe food for human consumption (Pan, Huang, & Wan, 2010). Therefore, FSMS provides a framework of planned systematic activities to identify, minimise or eliminate the possibility of hazard in food, besides providing control at all stages in the food chain. The important aspect of ISO 22000 is the assurance given by the standard in the whole of value chain namely raw materials, process, product distribution chain and management beside the peripheral requirements contributing to the overall quality of the product including upgradation of technology, machinery manpower and product safety aspects (Psomas et al., 2018).

Components of ISO 22000: 2005 standard

The ISO 22000 quality management systems includes verifiable parameters with reference to incidence, analysis and mitigation of hazards, communications (external and in-house), responsibility designation, implementation of risk management, continuous improvement, and good health practices. The system also facilitates differentiating with the help of ISO 22000 organizations can easily differentiates between critical control points (CCPs), operational PRP (OPRP) and PRP.

Prerequisite programme

The pre requisite programmes are "basic conditions and activities that are necessary to maintain a hygienic environment throughout the food chain suitable for the production, handling and provision of safe end products". These are defined by different nomenclature for different environment namely good agriculture practice (GAP), good laboratory practice, good hygienic practice (GHP), good manufacturing practice (GMP), good aquaculture practices (GAqP), good transport practice (GTP), good storage practice (GSP), good retail practice, good catering practice, good veterinarian practice, good housekeeping practice, good production practice, good distribution practice, good trading practices etc. (Raspor & Ambrozic, 2012).

Table 3 Major components of pre-requisite programme

1.	Structure and layout of buildings and linked utilities
2.	Layout of premises, including workspace and employee facilities
3.	Supplies of air, water, energy and other utilities
4.	Supporting services, including waste and sewage disposal
5.	Equipment suitability and accessibility for easy cleaning, repairs and preventative maintenance
6.	Management of purchased materials (e.g., raw materials, ingredients, chemicals, and packaging), supplies (e.g., water, air, steam, and ice), disposals (e.g., waste and sewage), handling of rework and products (e.g., storage and transportation)
7.	Measures for the prevention of cross-contamination
8.	Cleaning and sanitizing
9.	Pest control
10.	Personal hygiene
11.	Trainings

These PRPs must be put in practice before implementing HACCP. The PRP and HACCP together contribute to the required effect along the value chain in the elimination hazards. Most important requirements for implementation PRPs, as given in ISO 22000, are given in Table 3 (Allata et al., 2017). PRPs ensure hygienic conditions throughout the food chain suitable for the production of safe food for human consumption. The decision tree which can be followed in finalising the type of control namely PRP, OPRP or HACCP etc. is given in Fig 1.

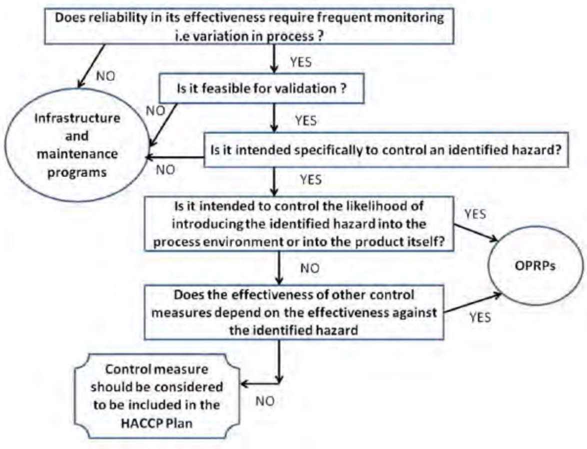

Fig 1 Decision tree approach to categorize PRPs *(Adopted from Panghal et al., 2017)*

Operational prerequisite programme (OPRP)

The pre-requisite programme identified by hazard analysis which are crucial to control the entry of hazard in to the production environment is called operational PRP and are essential to control product-specific hazards that are not controlled through CCP. It is therefore very important to identify during hazard analysis whether the incidence of hazard is controlled by PRP or OPRP.

The ISO 24000 clearly indicates that the decision on the type of control is important to get a full proof control on the system as higher the hazard level or its frequency of occurrence, the control measure belongs to the HACCP plan. Similarly, more severe is the hazard on consumer health the higher the possibility that the control belongs to HACCP plan. PRP, OPRP and CCP can be a standalone or combination measure in control hazards in a food production system but frequently OPRP is product specific. In other words, OPRPs control the likelihood of introduction of contamination and its proliferations while PRPs ensure strictly ensure sanitary and hygiene production environment. Also, PRP is general applicable to the whole system while the OPRP and CCP are product specific (Fig 2).

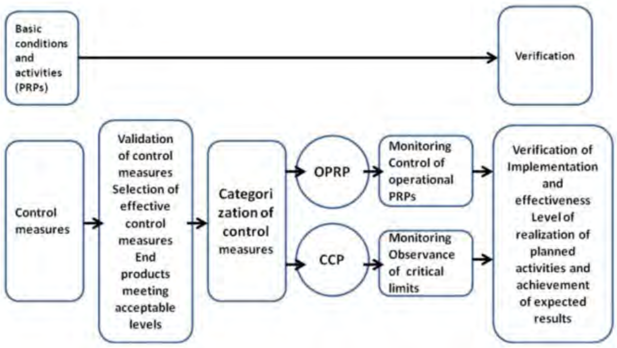

Fig 2. System approach to control and verification

(Adopted from Panghal et al., 2017)

Hazard Analysis and Critical Control Point (HACCP):

HACCP is a systematic and science-based HACCP system identifies specific hazards

and measures for their control in order to ensure food safety. HACCP mainly focusses on prevention instead of relying on end product testing only (Raspor & Ambrozic, 2012). The principle involved in HACCP are given in Table 4. The of HACCP is not a "stand alone" programme in a food processing facility but need to be built on other food safety programs such as GMP, PRP etc. that are practiced by the facility and will address food safety and food quality issues that are not critical for the reduction of food safety hazards.

The system is effective only when there is absolute a critical observation at different stages of the production process starting from raw material purchase to finished product and further till it reaches the consumer (Montville & Matthews, 2007). Greater emphasis is given on the continuous improvement with improved food safety performance, derived through the establishment and achievement of tangible food safety objectives. The important components for effective implementation include having a thoroughly understood food safety policy for the organisation, emergency preparedness and quick response system to act in the event of a hazard incidence and presence of a traceability system for every component used in the production process.

With respect to implementation there is always a confusion on the type of standard to be implemented for food products. It is clear that ISO 22000:2005 is concerned with food safety while the ISO 9001 ensures quality. Therefore, it is often considered together. It is also a fact that ISO 22000: 2005 includes both the systems namely HACCP and ISO 9001. The arrival of several private standards also leads to the confusion on the suitability of the standards but it is reported that the harmonisation of national with global standards takes care of this to a large extent (Fernandez-Segovia et al., 2014).

Certification process

The procedure for FSMS certification of organization involves first the implementation of management system, which after review need to be certified following the norms. Then a preaudit is carried out to demonstrate the gap between the documents and the system and appropriate measures are taken up to harmonise the gaps a full audit followed by the conformation audit to follow up the nonconformities in the audit which is followed by certification. After that surveillance audit is carried out as per the norms of the certifying organisation and the certification is maintained.

Table 4 Principles and description of HACCP

	Principle	Description of principle
1	Conduct a Hazard Analysis	Listing the steps in the process and identifying where significant hazards are likely to occur
2	Identify the Critical Control Points	A critical control point (CCP) is a point, step or procedure at which control can be applied and a food safety hazard can be prevented, eliminated or reduced to acceptable levels. Identification of the critical control points in the process. A critical control point may control more than one food safety hazard or in some cases more than one CCP is needed to control a single hazard. The number of CCP's needed depends on the processing steps and the control needed to assure food safety.
3	Establish Critical Limits	A critical limit (CL) is the maximum and/or minimum value to which a biological, chemical, or physical parameter must be controlled at a CCP to prevent, eliminate, or reduce to an acceptable level the occurrence of a food safety hazard. The critical limit is usually a measure such as time, temperature, water activity (Aw), pH, weight, or some other measure that is based on

		scientific literature and/or regulatory standards.
4	Monitor CCP	The monitoring procedures for the measurement of the critical limit at each critical control point is addressed. Monitoring procedures should describe how the measurement will be taken, when the measurement is taken, who is responsible for the measurement and how frequently the measurement is taken during production.
5	Establish Corrective Action	Corrective actions are the procedures that are followed when a deviation in a critical limit occurs. The steps that will be taken to prevent potentially hazardous food from entering the food chain will be identified along with the steps for correct measure. This usually includes identification of the problems and the steps taken to assure that the problem will not occur again.
6	Verification	Those activities, other than monitoring, that determine the validity of the HACCP plan and that the system is operating according to the plan. This includes activities such as auditing of CCP's, record review, prior shipment review, instrument calibration and product testing as part of the verification activities.
7	Documentation	A key component of the HACCP plan is recording information that can be used to prove that a food was produced safely. The records need to include information about the HACCP plan. Record should include information on the HACCP Team, product description, flow diagrams, the hazard analysis, the CCP's identified, Critical Limits, Monitoring System, Corrective Actions, Recordkeeping Procedures, and Verification Procedures.

Private Food Safety Standards

Another situation is the use of private FSMS standards designed by non-governmental entities, such as food industry stake holder groups (Manning et al., 2006), individual retailers or retailing groups and industry associations. The major player in this context is British Retail Consortium (BRC) Food, FSSC 22000, IFS Food, Dutch HACCP and other proprietary retailer standards. The BRC Global Standard for Food Safety developed and published in 1998 by BRC, a stakeholder group of British Retailers Consortium. FSSC 22000 developed by , which includes requirements of ISO 22000, ISO 22002-1 and other additional the Foundation for Food Safety Certification (FSSC), founded in 2004, IFS food standard developed by the collaboration of three retail federations from Germany, France and Italy, SCV certification by the National Board of Experts HACCP – The Netherlands, Global Red Meat Standard, published by the Danish Agriculture & Food Council, Safe Quality Food (SQF) owned and managed by the Food Marketing Institute (FMI) based in Virginia, the PrimusGFS food safety audit scheme, owned and managed by Azzule Systems, United States and Proprietary FSMS standards owned by individual organizations such as a retail chains and are enforced in their supply chains (Rafeeque and Sekharan, 2018).

No doubt the presence of certification or accreditation increases customer acceptability and satisfaction. But the main issue is the sector wise non-availability of standards and is often developed based on the need of the sector as voluntary standard or adoption of a national standard. This creates a sort of confusion in the global business. Another issue for the industry is the increasing cost of certification or accreditation. However, standardization of guidelines simplifies the process, ensures better planning and resource optimization as well as reduces cost, enhances efficiency, wider applicability and improves documentation.

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32. Seafood quality assurance and safety regulations

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Food Safety has been the buzz word in recent days as there are increasing consumer awareness on hazards present in food as well as the ombudsmen role played by independent media. Although regulatory regime across the world has taken proactive steps, in most of the cases it has been a knee-jerk reaction to the impending crisis. Defining the actual goal of food safety has been an arduous task as there are umpteen interrelated factors that influence the intended goals. Some of the definitions on food safety put forward by international agencies are as follows:

- Concept that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use (ISO 22000:2005)
- A suitable product which when consumed orally either by a human or an animal does not cause health risk to consumer (USDA-FSIS)
- Range of food related activities from prevention and surveillance to detection and control (ASTHO)

Food Safety also encompasses many aspects of handling, preparation and storage that introduces or controls chemical, microphysical and microbiological hazards. Quality of raw material, presence of pathogens, processing methods, climate change and cross-contamination also significantly impacts any food safety measure.

Seafood is always in news as it is proclaimed to be most nutritious and healthy food as well as being linked to increasing number of foodborne outbreaks across the globe. In the nutritional front, fish accounts for 17 percent of the global population intake of animal protein and 6.7% of all protein consumed (FAO, 2016). The world per capita consumption of fish and fishery products has increased from 9.9 Kg in 1960s to 20 Kg in 2014.

Seafood trade apart from being highly volatile accounts for 10 percent of total agricultural exports and 1 percent of world merchandise trade in value terms. In 2010, the quantum of seafood trade has crossed US$109 billion. Ninety percent of global trade in fish and fishery products consists of processed products, where 39% of the total quantity is traded as frozen. This trend indicates high mobility of the fishery products across the globe, which demands stringent traceability system in place to track the movement of the commodity from harvest to consumers. Nearly 75% of the volume of seafood in international trade is imported by developed nations and 50% of that is exported by developing nations. Hence, food safety issues concerned with seafood is no more local or restricted to a particular geographical location, but has acquired global dimension. Some of the major food safety concerns linked to seafood are:

- presence of Ciguatera toxin in reef dwelling finfish

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- histamine fish poisoning
- norovirus and *Vibrio parahaemolyticus* in raw shellfish
- *Salmonella* in shrimp products
- *Clostridium botulinum* in processed products
- high level of environmental pollutants
- mercury, cadmium, lead
- polychlorinated biphenyls and pesticides
- antimicrobial residues in aquaculture products

Apart from the above-mentioned concerns which are mostly global, there are regional issues like use of adulterants like formaldehyde to retard decomposition process, ammonia to mask spoilage, use of un-approved additives (preservatives), high level of pesticides in dry fish and presence of emerging pathogens in fisheries environs.

The most challenging task for the policy makers has been to link incidences of foodborne illnesses with a particular food commodity. It needs a strong surveillance and monitoring mechanism to unequivocally attribute a particular food commodity. In USA, Centre for Disease Control (CDC) does the massive work of source tracking for major foodborne pathogens through pulse net programmes. The recent report by CDC (Scallan et al., 2011) indicates that 31 major pathogens reported in the United States caused 9.4 million episodes of foodborne illness, 55,961 hospitalizations and 1,351 deaths during 2. Most (58%) illnesses were caused by norovirus, followed bynon-typhoidal *Salmonella* spp. (11%), *Clostridium perfringens* (10%), and *Campylobacter* spp. (9%). Leading causes of hospitalization were nontyphoidal *Salmonella* spp. (35%), norovirus (26%), *Campylobacter* spp. (15%), and *Toxoplasma gondii* (8%). Leading causes of death were non-typhoidal *Salmonella* spp. (28%), *T. gondii* (24%), *Listeria monocytogenes* (19%), and norovirus (11%). In India, the recently established National Centre for Disease Control (formerly, National Institute of Communicable Diseases), Ministry of Health and Family Welfare, Government of India has a similar mandate to undertake activities on outbreak investigation and provide referral diagnostic services.

In absence of etiological data linked to seafood, the export rejection figures provides an indirect account of food safety hazards associated with seafood. Import refusals and rejections from countries like USA, Japan, Russia and EU are on the rise because of presence of biological and chemical hazards in seafood, leading to heavy economic loss by seafood industries. The most common import refusal of seafood by USA is due to presence of *Salmonella*, *Listeria*, filth or illegal veterinary drugs. The RASFF portal of EU indicates alert notifications due to presence of veterinary drug residues, heavy metals, histamine, foreign bodies, biotoxin, defective packaging, incorrect labelling, improper health certificate, unapproved colour and additives and organoleptic aspects. In recent months most of the rejections from Japan had been due to presence of furazolidone (AOZ) and Ethoxyquin in shrimp. Seafood rejections from Russia are mostly due to presence of high load of mesophilic bacteria, coliforms, pathogens and presence of crystal violet.

Genesis of Food Safety Standards and Regulations

Food safety standards can be classified as regulatory, voluntary, Government/Statutory, private, domestic, international or benchmarked depending upon its scope and range of application. Most of these standards have evolved based upon sanitary and phyto-sanitary (SPS) requirements, economic interest, risk analysis or as precautionary approach. The precautionary approach mostly relies on perception i.e. equivalent level of protection, appropriate level of protection (ALOP) or as low as reasonably achievable (ALARA).

In international trade, sanitary and phytosanitary measures are envisioned to be based on sound scientific principles that ensure food safety and do not anyway compromise the production potential and resources of a particular country. These measures should not be linked to prevent market access based on non-scientific reasons, and are requirements but not sufficient condition of trade. As per the Annex A of WTO Agreement, Sanitary and phytosanitary measures are applied to (i) protect animal or plant life or health within the territory of the Member from risks arising from the entry, establishment or spread of pests, diseases, disease-carrying organisms or disease-causing organisms (ii) to protect human or animal life or health within the territory of the Member from risks arising from additives, contaminants, toxins or disease-causing organisms in foods, beverages or feedstuffs (iii) from risks arising from diseases carried by animals, plants or products thereof, or from the entry, establishment or spread of pests and (iv) to prevent or limit other damage within the territory of the Member from the entry, establishment or spread of pests. WTO encourages members to use accepted International standards by Codex Alimentarius Commission, OIE (World Organization for Animal Health) and IPPC (International Plant Protection Convention). Countries may introduce or maintain SPS measures that provide higher level of protection than the current international or Codex standards.

Salient features of some Export regulations related to Seafood European Union

European Union is the biggest importer of fish and fishery products in the world. The food safety regulations set by EU is harmonised, gets periodically updated, transparent and based on principles of risk assessment. The key elements of EU requirements for import of seafood are (a) certification by a competent authority (b) compliance to hygiene and public health requirements in terms of structure of vessels, landing sites, processing establishments and on operational processes, freezing and storage (c) certified production area for bivalves (d) national control plan on heavy metals, contaminants, residues of pesticides and veterinary drugs (e) approval of establishments.

The legal acts of EU are managed through regulations, directives, decision, recommendations and opinions.

Regulation: A binding legislative act applied in entirety across EU

Directives: A "directive" is a legislative act that sets out a goal that all EU countries must achieve.

Decision: A "decision" is binding on those to whom it is addressed (e.g. an EU country or an individual company) and is directly applicable.

Recommendations: A "recommendation" is not binding act that allows the institutions to make their views known and to suggest a line of action without imposing any legal obligation on those to whom it is addressed.

Opinions: An "opinion" is an instrument that allows the institutions to make a statement in a non-binding fashion, in other words without imposing any legal obligation on those to whom it is addressed.

Some of the important EU legislations related to food safety issues of fish and fishery products are as follows:

Regulation (EC) No 178/2002: General principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety

Regulation (EC) No 852/2004: Hygiene of foodstuffs.

Regulation (EC) No 853/2004: Specific hygiene rules for food of animal origin

Regulation (EC) No 854/2004: Specific rules for the organisation of official controls on products of animal origin intended for human consumption

Regulation (EC) No 2073/2005: Microbiological criteria for foodstuffs

Regulation (EC) No 882/2004: Official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules

Regulation (EC) No 1881/2006: Maximum levels for certain contaminants in foodstuffs

Regulation (EC) No 333/2007: Methods of sampling and analysis for the official controls for the levels of lead, cadmium, mercury, inorganic tin, 3- MCPD and benzo(a)pyrene in foodstuffs

Regulation (EC) No 1883/2006: Methods of sampling and analysis for the official control of levels of dioxins and dioxin-like PCBs in certain foodstuffs

Regulation (EC) No 396/2005: Maximum residue levels of pesticides in or on food and feed of plant and animal origin

Council Directive 96/23/EC: Measures to monitor certain substances and residues thereof in live animals and animal products

Commission Decision (2005/34/EC): Harmonised standards for the testing for certain residues in products of animal origin imported from third countries

Commission Decision (2002/657/EC): Implementing Council Directive 96/23/EC concerning the performance of analytical methods and the interpretation of results

Commission Decision (98/179/EC): Official sampling for the monitoring of certain substances and residues thereof in live animals and animal products

Commission Decision (2004/432/EC): Approval of residue monitoring plans submitted by third countries in accordance with Council Directive 96/23/EC

Council Directive 96/22/EC: Prohibition on the use in stock farming of certain substances having a hormonal or thyrostatic action and of betaagonists

Regulation (EC) No 470/2009: Community procedures for the establishment of residue limits of pharmacologically active substances in foodstuffs of animal origin

Commission Regulation (EU) No 37/2010: Pharmacologically active substances and their classification regarding maximum residue limits in foodstuffs of animal origin

Commission Regulation (EC) No 2023/2006: Good manufacturing practice for materials and articles intended to come into contact with food

Commission Regulation (EC) No 1935/2004: Materials and articles intended to come into contact with food

Commission Regulation (EU) No 1129/2011: Amendment to Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the

Council by establishing a Union list of food additives Commission Regulation (EC) No

1333/2008 : Food Additives
Commission Regulation (EC) No 1334/2008: Flavourings and certain food ingredients with flavouring properties for use in and on foods
Commission Regulation (EC) No 1331/2008: Establishing a common authorisation procedure for food additives, food enzymes and food flavourings
Directive 2000/13/EC: Labelling, presentation and advertising of foodstuffs (until 12 December 2014)
Commission Regulation (EU) No 1169/2011: Provision of food information to consumers, amending Regulations
Commission Regulation (EU) No 1379/2013: Common organisation of the markets in fishery and aquaculture products

USA

In USA both Federal and State Regulatory agencies are involved in ensuring safety and quality of seafood. Multiple federal agencies are involved in regulatory oversight of seafood for both importation and export.

United States Department of Agriculture (USDA) oversees the implementation of country-of-origin labelling (COOL) regulation enacted under the Farm Security and Rural Investment Act of 2002. This law requires that all retailers, such as full-line grocery stores or supermarkets must notify their customers with information regarding the source of certain foods. The COOL regulation for fish and shellfish (7 CFR Part 60) came into force in 2005. Apart from the country of origin, all fish and shellfish covered commodities must be labelled to indicate whether they are wild caught or farm-raised.

United States Fisheries and Wildlife Service (USFWS) is also involved in regulation of import and export of shellfish and fishery products through Convention on International Trade in Endangered Species (CITES) act (50 CFR Part 23), Endangered Species Act (50 CFR Part 17), General Permit Procedures (50 CFR Part 13), Lacey Act (injurious wildlife) (50 CFR Part 16), Marine Mammal Protection Act (50 CFR Part 18) and Wildlife (import/export/transport) act (50 CFR Part 14). Live farm-raised fish and farm-raised fish eggs are exempted from export declaration and licensing requirements. Imports or exports of any sturgeon or paddlefish product, including meat, caviar, and cosmetics made from sturgeon eggs, dead uneviscerated salmon, trout and char and live fertilized eggs from these salmonid fish require a permit. Aquatic invertebrates and other animals that are imported or exported for human or animal consumption but that do not meet the definition of shellfish such as squid, octopus, cuttlefish, land snails, sea urchins, sea cucumbers and frogs are also covered under these provisions.

National Oceanic and Atmospheric Administration (NOAA) functioning under the United States Department of Commerce (USDC) provides voluntary seafood inspection program for fish, shellfish, and fishery products to the industry as per the 1946 Agricultural Marketing Act. The NOAA Seafood Inspection Programme often referred to as the U.S. Department of Commerce (USDC) Seafood Inspection Programme provides services such as establishment sanitation inspection, system and process audits, product inspection and grading, product lot inspection, laboratory analyses, training, consultation and export certification. NOAA Fisheries is the Competent Authority for export health certification and IUU catch documentation for US seafood products meant for export to EU and non-EU countries.

The U.S. Food and Drug Administration (USFDA) is vested with the primary Federal responsibility for the safety of seafood products in the United States. It operates a mandatory safety program for all fish and fishery products under the provisions of the Federal Food, Drug and Cosmetic (FD&C) Act, the Public Health Service Act, and related regulations. The most important regulation enacted by USFDA was "Procedures for the Safe and Sanitary Processing and Importing of Fish and Fishery Products" published as final rule 21 CFR 123 on 18th December 1995 and came into force on 18^{th} December 1997. It required processors to adopt the preventive system of food safety controls known as HACCP (Hazard Analysis and Critical Control Point). Seafood was the first food commodity in the U.S. to adopt HACCP in USA. For screening imports, USFDA uses a tool "Predictive Risk-based Evaluation for Dynamic Import Compliance Targeting (PREDICT)", that targets higher risk products for examination and sampling and minimizes the delay in shipments of lower risk products.

Food Safety and Modernization Act (FSMA) is the most important milestone event in the food safety scenario in USA. It was signed in to law on 4th January 2011 which sifted the focus from responding to a contamination to prevention of the actual cause. The salient features of FSMA act are as follows:

Sec. 103.Hazard analysis and risk-based preventive controls
(HARPC): Requires human and animal food facilities to

- evaluate hazards that could affect food safety;
- Identify and implement preventive controls to prevent hazards;
- Monitor controls and maintain monitoring records; and
- Conduct verification activities

Sec. 106.Protection against intentional adulteration
Sec. 111. Sanitary Transportation of Food
Sec. 301. Foreign supplier verification program
• Requires importers to verify their suppliers use risk-based preventive controls that provide same level of protection as U.S. requirements.
Sec. 302. Voluntary qualified importer program
Allows for expedited review and entry; facility certification required
Sec. 303. Certification for high-risk food imports
• FDA has discretionary authority to require assurances of compliance for high-risk foods
Sec. 304. Prior notice of imported food shipments
• Requires information on prior refusals to be added to prior notice submission
• Effective July 3, 2011
Sec. 307. Accreditation of third-party auditors
• FDA can rely on accredited third parties to certify that foreign food facilities meet U.S. requirements
Sec. 308. Foreign Offices of the Food and Drug Administration.
• Establish offices in foreign countries to provide assistance on food safety measures for food

exported to the U.S.

Sec. 309. Smuggled Food

• In coordination with DHS, better identify and prevent entry of smuggled food

• Rules on anti-smuggling strategy is already framed

China

In recent years China has strengthened its SPS measures and has taken a number of precautionary steps to ensure safety to its population. Some of the important regulations enacted by Peoples Republic of China are as follows:

- GB 2763—2012: National food safety standard on Maximum residue limits for pesticides in food
- GB 2762—2012: National food safety standard on Contaminants in Food
- GB-2010: National Food Safety Standard for Pathogen Limits in Food (GAIN Report No. 12063)
- GB 2733-2005: Hygienic Standard for Fresh and Frozen Marine Products of Animal Origin
- GB 2760-2011 additives
- GB 10136-1988 Hygienic standard for salt & liquor-saturated aquatic products of animal origin

Russia

Russia has a comprehensive regulatory framework for fish and fishery products. The hygienic requirements are different from other countries as some of the microbiological parameters are expressed as absent in 0.001g or 0.01g. Also some different nomenclature like QMAFAnM is followed instead of APC. The Russian regulation currently in force pertaining to fish and fishery products are as follows:

- Hygienic requirements for safety and nutrition value of food products. Sanitary and epidemiological rules and regulations, sanpin 2.3.2.1078-01

Japan

Compared to other countries, SPS measures followed by Japan is very stringent. Many additives which are in the approved list of Codex are banned or prohibited in Japan. Japan uses a positive list system for MRL of agricultural chemicals in foods. A uniform limit of 0.01 ppm is followed for the compounds for which no risk assessment is done but which are included in the positive list (MHLW Notification No. 497, 2005). MHLW uses a toxicological threshold of 1.5 µg/day as the basis to determine the uniform limit. Substances having no potential to cause damage to human health are specified by MHLW Notification No.498. 2005. The MRL list is mentioned as compositional specification of foods (MHW Notification, No. 370, 1959, amendment No.499 2005, updated as on March 15, 2013). The relevant food safety acts of Japan as enacted by Ministry of Health, Labour and Welfare and other agencies are as follows:

- Food Sanitation Act (Act No.233, 1947): Latest Revision on June 5, 2009, Act No. 49)
- Specifications and Standards for Food and Food Additives, Latest Revision on September 6, 2010, MHLW Notification No. 336

- Japan's Specifications and Standards for Food Additives" (Eighth Edition). Published by the Ministry of Health, Labour and Welfare in 2007
- Food Safety Basic Act (Act No. 48, 2003)
- Agricultural Chemicals Regulation Law (Law No. 82, 1948)

Codex Alimentarius Commission

The Codex Alimentarius Commission (CAC) was established in 1961- 1963 by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) to implement their Joint FAO/WHO Food Standards Programme. CAC has the mandate to formulate food standards, code of practice, guidelines and recommendations to protect health of consumers, ensure fair practices in food trade and to promote coordination of all food standards work undertaken by international governmental and non-governmental organizations. Codex operates through thee standing expert scientific bodies convened under the auspices of FAO and WHO to generate food data and provide risk-assessment type advice:

- Joint Expert Committee on Food Additives (JECFA)
- Joint Meeting on Pesticide Residues (JMPR)
- Joint Meeting on Microbiological Risk Assessment (JEMRA)

Different subject committees and commodity committees, adhoc intergovernmental task forces and regional coordinating committees' function and under codex. Codex Committee on Fish and Fisheries Products (CCFFP) is entrusted with the task of formulating standards for different product categories. Although Codex standards on Fish and Fishery Products specifically do not address food safety requirements, but provide a strong framework for production, hygienic requirements and sampling.

Available Codex Standard for Fish and Fishery Products

1.	Standard for Canned Salmon	CODEX STAN 3-1981
2.	Standard for Quick Frozen Finfish, Eviscerated or Uneviscerated	CODEX STAN 36-1981
3.	Standard for Canned Shrimps or Prawns	CODEX STAN 37-1981
4.	Standard for Canned Tuna and Bonito	CODEX STAN 70-1981
5.	Standard for Canned Crab Meat	CODEX STAN 90-1981
6.	Standard for Quick Frozen Shrimps or Prawns	CODEX STAN 92-1981
7.	Standard for Sardines and Sardine-Type Products	CODEX STAN 94-1981
8.	Standard for Quick Frozen Lobsters	CODEX STAN 95-1981
9.	Standard for Canned Finfish	CODEX STAN 119-1981
10	Standard for Quick Frozen Blocks of Fish Fillets, Minced Fish Flesh and Mixtures of Fillets and Minced Fish Flesh	CODEX STAN 165-1989
11	Standard for Quick Frozen Fish Sticks (Fish Fingers), Fish Portions and Fish Fillets - Breaded or in Batter	CODEX STAN 166-1989
12	Standard for Salted Fish and Dried Salted Fish of the Gadidae Family of Fishes	CODEX STAN 167-1989
13	Standard for Dried Shark Fins	CODEX STAN 189-1993
14	General Standard for Quick Frozen Fish Fillets	CODEX STAN 190-1995
15	Standard for Quick Frozen Raw Squid	CODEX STAN 191-1995
16	Standard for Crackers from Marine and Freshwater Fish, Crustaceans and Molluscan Shellfish	CODEX STAN 222-2001
17	Standard for Boiled Dried Salted Anchovies	CODEX STAN 236-2003
18	Standard for Salted Atlantic Herring and Salted Sprat	CODEX STAN 244-2004
19	Standard for Sturgeon Caviar	CODEX STAN 291-2010
20	Standard for Live and Raw Bivalve Molluscs	CODEX STAN 292-2008
21	Standard for Fish Sauce	CODEX STAN 302-2011

Code of Practice

Code of Practice for Fish and Fishery Products	CAC/RCP 52-2003

Guidelines

Guidelines for the Sensory Evaluation of Fish and Shellfish in Laboratories	CAC/GL 31-1999
Guidelines on the Application of General Principles of Food Hygiene to the Control of Pathogenic Vibrio Species in Seafood	CAC/GL 73-2010
Guidelines on the Application of General Principles of Food Hygiene to the Control of Viruses in Food	CAC/GL 79-2012
Model Certificate for Fish and Fishery Products	CAC/GL 48-2004
Guideline Procedures for the Visual Inspection of Lots of Canned Foods for Unacceptable Defects	CAC/GL 17-1993
Guidelines on Good Laboratory Practice in Pesticide Residue Analysis	CAC/GL 40-1993
General guidelines on sampling	CAC/GL 50-2004
Guidelines on the Use of Mass Spectrometry (MS) for Identification, Confirmation and Quantitative Determination of Residues	CAC/GL 56-2005

Codex standard applicable to Fish and Fishery Products

General Standard for Contaminants and Toxins in Food and Feed	CODEX STAN 193-1995
General Standard for the Labelling of Prepackaged Foods	CODEX STAN 1-1985
Standard for Food Grade Salt	CODEX STAN 150-1985
General Standard for Food Additives	CODEX STAN 192-1995
General Methods of Analysis for Contaminants	CODEX STAN 228-2001
Recommended Methods of Analysis and Sampling	CODEX STAN 234-1999
General Methods of Analysis for Food Additives	CODEX STAN 239-2003

Bureau of Indian Standards (BIS)

Bureau of Indian Standards (BIS) functioning under the Ministry of Consumer Affairs, Food and Public Distribution, Government of India. It came into existence on 01 April 1987 through an Act of Parliament on 26 November 1986. It was functioning previously as Indian Standards Institution which was established on 06 January 1947. BIS has so far formulated 64 standards related to fish and fishery products, out of which 33 are active. All these standards are voluntary, which addresses method of production, quality and safety requirements. It also stipulates the method of testing and sampling. There is an attempt by FSSAI to re-draft all BIS standards related to fish and fishery products as most of the food safety requirements are not in sync with the current national standards.

BIS Standards on Fish and Fishery Products

IS 2168	1971	Pomfret Canned in Oil
IS 2236	1968	Prawns/Shrimp Caned in Brine
IS 2237	1997	Prawns (Shrimps) - Frozen
IS 3336	1965	Shark Liver Oil for Veterinary Use
IS 3892	1975	Frozen Lobster Tails
IS 4304	1976	Tuna Canned in Oil
IS 4780	1978	Pomfret, Fresh
IS 4793	1997	Whole Pomfret - Frozen
IS 5734	1970	Sardine Oil
IS 6121	1985	*Lactarius* sp Canned in Oil
IS 6122	1997	Seer Fish (*Scomberomorus* Sp.) - Frozen
IS 6123	1971	Seer Fish (*Scomberomorus* spp.), Fresh
IS 7143	1973	Crab Meat Canned in Brine
IS 7313	1974	Glossary of Important Fish Species of India
IS 7582	1975	Crab Meat, Solid Packed
IS 8076	2000	Frozen Cuttlefish and Squid
IS 9808	1981	Fish Protein Concentrate
IS 10059	1981	Edible Fish Powder
IS 10760	1983	Mussels Canned in Oil
IS 10762	1983	Tuna Canned in Curry
IS 10763	1983	Frozen Minced Fish Meat
IS 11427	2001	Fish and Fisheries Products - Sampling
IS 14513	1998	Beche-de-mer
IS 14514	1998	Clam Meat - Frozen
IS 14515	1998	Fish Pickles
IS 14516	1998	Cured fish and fisheries products - Processing and storage - Code of Practice
IS 14517	1998	Fish Processing Industry - Water and Ice - Technical Requirements
IS 14520	1998	Fish Industry - Operational Cleanliness and layout of market - Guidelines (Amalgamated Revision of IS 5735, 7581 and 8082)
IS 14890	2001	Sardines - Fresh, Frozen and Canned (Amalgamated revision of IS 2421, 6677,8652,8653, 9750 and 10761
4891	2001	Mackerel - Fresh, Frozen and Canned (Amalgamated Revision of IS 2420, 3849,6032, 6033 and 9312)
IS 14892	2000	Threadfin - Fresh and Frozen
IS 14949	2001	Accelerated Freeze Dried Prawns (Shrimps) (Amalgamated revision of IS 4781 and 4796
IS 14950	2001	Fish - Dried and Dry-Salted

Food Safety and Standards Authority of India (FSSAI)

The Food Safety and Standards Authority of India was established under the Food Safety and Standards Act, 2006 as a statutory body for laying down science-based standards for articles of food and regulating manufacturing, processing, distribution, sale and import of food so as to ensure safe and wholesome food for human consumption. Various central acts including the erstwhile Prevention of Food Adulteration Act (1954) were merged under this act The Food Safety and Standards Regulations (FSSR) came into force in 2011, which is

divided to following sections:
FSS (Licensing and Registration of Food businesses) regulation, 2011

- FSS (Packaging and Labelling) regulation, 2011
- FSS (Food product standards and Food Additives) regulation, 2011 (part I)
  FSS (Food product standards and food additives) regulation, 2011
  (part II)
- FSS (Prohibition and Restriction on sales) regulation, 2011
- FSS (contaminants, toxins and residues) regulation, 2011
- FSS (Laboratory and sampling analysis) regulation, 2011

Recently, standards related to microbiological specifications of fish and fishery products, limit of heavy metals, PAH, PCBs and biotoxins have been incorporated in the FSSR.

HACCP CONCEPT IN SEAFOOD QUALITY ASSURANCE

Concept of HACCP was developed in the late 1950s and initiated in the early 1960s by the Pillsbury Company, in collaboration with NASA and the Natick Laboratories of the U.S. Army, and the U.S. Air Force Space Laboratory Project Group. The concepts designed were based on the principles of Failure Mode and Effect analysis (FEMA). It was first presented to regulatory community during National Conference on Food Protection in 1971 by Howard Bauman of the Pillsbury Company and first applied to low acid canned foods in 1974. In 1980s, other food processing companies embraced it voluntarily and at the same time FDA and USDA continued regulatory interest. HACCP gained regulatory approval from USFDA and USDA after it was endorsed by National Academy of Sciences and further by 9National Advisory Committee on Microbiological Specifications of Foods (NACMSF). On December 18, 1995, The Food and Drug Administration (FDA) published as a final rule 21 CFR 123, "Procedures for the Safe and Sanitary Processing and Importing of Fish and Fishery Products" that requires processors of fish and fishery products to develop and implement Hazard Analysis Critical Control Point (HACCP) systems for their operations. The regulation became effective December 18, 1997. HACCP was recommended by Codex Alimentarius Commission (CAC) in 1997 which is recognized as “Recommended International Code of Practice-General Principles of Food Hygiene” (CAC/RCP 1-1969, Rev 3, 1997). In European countries, the EU Directive 93/43/EEC mandated the implementation of HACCP in all local legislation by December 1995. Subsequently the EC hygiene regulations 852/2004 and 853/2004 mandated that all food business operators should establish and operate food safety programmes and procedure based on HACCP principles. Since then HACCP has gained acceptance by many countries in Europe, Canada, New Zealand, Australia, Central and South America and many Asian countries. In India voluntary HACCP standards are given by Bureau of Indian Standards (IS 15000:1998).

Hazard Analysis Critical Control Point (HACCP)

The HACCP system is an internationally recognized system used to manage food safety. It has been endorsed by the Codex Alimentarius Commission as a tool that can be used to systematically identify hazards specific to individual products and processes and describe measures for their control to ensure the safety of fish and fish products. It is a dynamic system, capable of accommodating change in the system viz., changes in equipment design, processing procedures and technological advancements.

HACCP is defined as a system which identifies, evaluates, and controls hazards which are significant for food safety

HACCP is a structured, systematic approach for the control of food safety throughout the food system, from the farm to fork. It requires a good understanding of the relationship between cause and effect in order to be more pro-active. HACCP is supported by pre-requisite programmes like Good Manufacturing Practice (GMP), Good Hygienic Practices (GHP), SSOP (Sanitation standard operating procedures), Good Agricultural Practices (GAP), and Good Storage Practices (GSP), etc.

Pre-requisite programmes

Prerequisite programs provide a foundation for an effective HACCP system. They are often facility-wide programs rather than process or product specific. They reduce the likelihood of certain hazards. Prerequisite programs set the stage for a HACCP system and provide on-going support for the establishment's food safety system. They keep potential hazards from becoming serious enough to adversely impact the safety of foods produced. Without clean working conditions free from microbiological, chemical, and physical contamination from many sources, a HACCP plan cannot be effective.

Prerequisite programmes are practices and conditions needed prior to and during the implementation of HACCP and which are essential for food safety -WHO

Some of the prerequisite programmes include GAP, GMP and GHP which must be working effectively within a commodity system before HACCP is applied. Establishments should revise their prerequisite programs, as necessary, to ensure their effectiveness, and should take appropriate corrective actions when they determine that their prerequisite programs may have failed to prevent contamination and/or adulteration of product. Good Agricultural Practices are "practices that address environmental, economic and social sustainability for on-farm processes, and result in safe and quality food and non-food agricultural products" (FAO).

The Good Manufacturing Practices commonly referred as current good manufacturing practices (cGMPs, 21 CFR 110) give details as to what specific procedures must be followed to comply with the regulation. Standard operating procedures (SOPs) are the steps your company takes to assure that the GMPs are met. They include stepwise procedures, employee training, monitoring methods, and records used by your company. Similarly, SSOP covers eight key sanitation conditions as required by USFDA.

Good hygiene practices include all practices regarding the conditions and measures necessary to ensure the safety and suitability of food at all stages of the food chain.

Basic principles of HACCP

There are seven discrete activities that are necessary to establish, implement and maintain a HACCP plan, and these are referred to as the 'seven principles' in the Codex Guideline (1997). The seven Principles of HACCP are

Principle 1: Conduct a hazard analysis.

Hazard: A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect.

Hazard analysis: The process of collecting and evaluating information on hazards and conditions leading to their presence to decide which are significant for food safety and therefore should be addressed in the HACCP plan.

Principle 2: Determine the Critical Control Points (CCPs)

A step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level.

Principle 3: Establish critical limits.

A criterion which separates acceptability from unacceptability, when monitoring a critical control point.

Principle 4: Establish a monitoring system

The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a CCP is under control.

Principle 5: Establish a procedure for corrective action,

Any action to be taken when the results of monitoring at the CCP indicate a loss of control.

Principle 6: Establish procedures for verification

The application of methods, procedures, tests and other evaluations, in addition to monitoring to determine compliance with the HACCP plan.

Principle 7: Establish documentation concerning all procedures and records appropriate to these principles and their application

Developing a HACCP plan (FAO guidelines)

The all-important principles form the essential requirements of a food safety system and are designed to ensure that enough precaution is taken so that any hazard which can interfere with consumer health is addressed. The first principle of HACCP is hazard analysis. But understanding the product thoroughly is extremely important to get an idea on the possible hazards which could be associated with the product so that appropriate action can be taken to control or minimize the hazard. The seven principles of HACCP are usually carried out in twelve steps, as given below.

Step 1 - Establish a HACCP team

Hazard profile is related to the commodity. Therefore, in order to understand fully the commodity, to identify the hazards associated, the CCP and to work out a control measures it is pertinent to have a team which has the knowledge about the product or commodity, its production process and shelf-life. This would facilitate the proper implementation of HACCP for the production of the product. Therefore, it is important that the HACCP team is made up of people from a wide range of disciplines. The team should include:

- A team leader to lead the group and direct the team to carry out the work as per the system requirements. He should be well versed with the techniques and manage the team members to contribute to the cause.

- A person conversant with the production system who knows full details of the flow of production.
- Persons from varied field viz., biochemist, microbiologist, toxicologist, quality control manager or an engineer with an understanding of particular hazards and associated risks.
- Others who are involved in the varied activates of the system viz., packaging specialists, raw material buyers, distribution staff or production staff, farmers, brokers, who are involved with the process, and have working knowledge of it in order to provide expert opinion.
- Possibly one person to help the team with secretarial requirements.

Task 2 - Describe the product

Understanding the product is the important step as the hazard associated with depends on the product. To start a hazard analysis, a full description of the product, including customer specification, should be prepared. This should include information relevant to safety regulation/target level, and composition, physical/chemical properties of the raw materials and the final product, the water activity of the product (aw), the pH etc. There should information on the packaging, storage and distribution as well as information on the temperature of storage, distribution, labelling information and shelf-life of the product. This information helps the audit team to understand the possible hazards and their control measures.

Task 3 - Identify the product's intended use

Information on the intended use of the commodity or product as well as the information on the mode of consumption viz., direct consumption, cooked before hazard analysis will have bearing on the hazard analysis. The nature of the target group for the product may also be relevant, particularly if it includes susceptible groups such as infants, the elderly, and the malnourished. The likelihood of misuse of a product should also be considered, such as the use of pet food as a human food, either by accident or design.

Task 4 - Draw up the commodity flow diagram

The first function of the team is inspecting the detailed commodity flow diagram (CFD) of the commodity system and the expertise of the production manager or product expert is important at this stage as far as hazard analysis is concerned.

Task 5 - On site confirmation of flow diagram

After studying the commodity flow diagram the team should visit the system where HACCP is implemented or proposed to be implemented which may include any step in the production viz., procurement of raw material, store, production area, packaging area, storage section where the product is kept before distribution, nature of distribution, conditions of distribution etc. The is known as ‘walking the line ‘, a step by step checking to get information on whether relevant requirements of the system are considered while making the production line. The site for which the HACCP plan is being designed should be visited as many times as possible to ensure that all relevant information has been collected.

Task 6 - Identify and analyse hazard(s) - (Principle 1)
Effective hazard identification and hazard analysis are the keys to a successful HACCP Plan. All real or potential hazards that may occur in each ingredient and at each stage of the commodity system should be considered. Food safety hazards for HACCP programmes have been classified into three types of hazards:

- Biological: typically, foodborne bacterial pathogens such as Salmonella, Listeria and E. coli, also viruses, algae, parasites and fungi.
- Chemical: There are three principle types of chemical toxins found in foods: naturally occurring chemicals, e.g. cyanides in some root crops, and allergenic compounds in peanuts; toxins produced by microorganisms, e.g. mycotoxins, and algal toxins; and chemicals added to the commodity by man to control an identified problem, e.g fungicidesor insecticides.
- Physical: contaminants such as broken glass, metal fragments, insects or stones.

The probability that a hazard will occur is called a risk. The risk may take a value from zero to one depending on the degree of certainty that the hazard will be absent or that it will be present. After hazard identification, a hazard analysis must be conducted to understand the relative health risk to man or animal posed by the hazard. It is a way of organizing and analysing the available scientific information on the nature and size of the health risk associated with the hazard. The risk may have to be assessed subjectively and simply classified as low, medium, or high. Once a food safety hazard has been identified, then appropriate control measures should be considered. These are any action or activity that can be used to control the identified hazard, such that it is prevented, eliminated, or reduced to an acceptable level. The control measure may also include training of personnel for a particular operation, covered by GAP, GMP, and GHP.

Task 7 - Determine the critical control points (CCPs) - (Principle 2).
Each step in the commodity flow diagram, within the scope of the HACCP study, should be taken in turn and the relevance of each identified hazard should be considered. The team must determine whether the hazard can occur at this step, and if so whether control measures exist. If the hazard can be controlled adequately, and is not best controlled at another step, and is essential for food safety, then this step is a CCP for the specified hazard. If a step is identified where a food safety hazard exists, but no adequate control measures can be put in place either at this step or subsequently, then the product is unsafe for human consumption. Production should cease until control measures are available and a CCP can be introduced.

Task 8 - Establish critical limits for each CCP - (Principle 3)
Critical limits must be specified and validated for each CCP. Criteria often used include measurements of temperature, time, moisture level, pH, water activity, and sensory parameters such as visual appearance. All critical limits, and the associated permissible tolerances, must be documented in the HACCP Plan Worksheet, and included as specifications in operating procedures and work instructions.

Task 9 - Establish a monitoring procedure - (Principle 4)

Monitoring is the mechanism for confirming that critical limits at each CCP are being met. The method chosen for monitoring must be sensitive and produce a rapid result so that trained operatives are able to detect any loss of control of the step. This is imperative so that corrective action can be taken as quickly as possible so that loss of product will be avoided or minimized. Monitoring can be carried out by observation or by measurement, on samples taken in accordance with a statistically based sampling plan. Monitoring by visual observation is basic but gives rapid results, and can therefore be acted upon quickly. The most common measurements taken are time, temperature and moisture content.

Task 10 - Establish corrective action - (Principle 5)

If monitoring indicates that critical limits are not being met, thus demonstrating that the process is out of control, corrective action must be taken immediately. The corrective action should take into account the worst-case scenario, but must also be based on the assessment of hazards, risk and severity, and on the final use of the product. Operatives responsible for monitoring CCPs should be familiar with and have received comprehensive training in how to effect a corrective action. Corrective actions must ensure that the CCP has been brought back under control. Corrective action can then be applied to pre-empt a deviation and prevent the need for any product disposition.

Task 11 - Verify the HACCP plan - (Principle 6)

Once the HACCP plan has been drawn up, and all of the CCPs have been validated, then the complete plan must be verified. Once the HACCP plan is in routine operation, it must be verified and reviewed at regular intervals. This should be a task of the person charged with the responsibility for that particular component of the commodity system. The appropriateness of CCPs and control measures can thus be determined, and the extent and effectiveness of monitoring can be verified. Microbiological and/or alternative chemical tests can be used to confirm that the plan is in control and the product is meeting customer specifications. A formal internal auditing plan of the system will also demonstrate an ongoing commitment to keep the HACCP plan up to date, as well as representing an essential verification activity.

Task 12 - Keep record - (Principle 7)

Record keeping is an essential part of the HACCP process. It demonstrates that the correct procedures have been followed from the start to the end of the process, offering product traceability. It provides a record of compliance with the critical limits set, and can be used to identify problem areas. Records that should be kept include: all processes and procedures linked to CCP monitoring, deviations, and corrective actions.

Steps involved in developing HACCP system

(Based on Codex 1997)

Step 1.	Assemble HACCP team	Preliminary Steps
Step 2.	Describe product	
Step 3.	Identify intended use	
Step 4.	Construct flow diagram	
Step 5.	On-site confirmation of flow diagram	
Step 6.	Conduct hazard analysis	HACCP Principle I
Step 7.	Determine Critical Control Points	HACCP Principle II
Step 8.	Establish critical limits for each CCP	HACCP Principle III
Step 9.	Establish a monitoring system for each CCP	HACCP Principle IV
Step 10.	Establish corrective actions	HACCP Principle V
Step 11.	Establish verification procedures	HACCP Principle VI
Step 12.	Establish Documentation and Record Keeping	HACCP Principle VII

HACCP is a core component in all national and international food safety standards such as IS 15000, ISO 22000:2005, USFDA Seafood HACCP regulation (CFR 123, Title 21), Dutch HACCP, BRC Global Standard for Food, SQF 2000, IFS, etc. Hence understanding concepts of HACCP would help in easy implementation of any food safety standard(s) deemed necessary to ensure safety of fish and fishery products.

Definitions in HACCP

Control (verb): To take all necessary actions to ensure and maintain compliance with criteria established in the HACCP plan.

Control (noun): The state wherein correct procedures are being followed and criteria are being met.

Control measure: Any action and activity that can be used to prevent or eliminate a food safety hazard or reduce it to an acceptable level.

Corrective action: Any action to be taken when the results of monitoring at the CCP indicate a loss of control.

Critical Control Point (CCP): A step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level.

Critical limit: A criterion which separates acceptability from unacceptability, when monitoring a critical control point.

Deviation: Failure to meet a critical limit.

Flow diagram: A systematic representation of the sequence of steps or operations used in the production or manufacture of a particular food item.

HACCP plan: A document prepared in accordance with the principles of HACCP to ensure control of hazards which are significant for food safety in the segment of the food chain under consideration.

Hazard: A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect.

Hazard analysis: The process of collecting and evaluating information on hazards and conditions leading to their presence to decide which are significant for food safety and therefore should be addressed in the HACCP plan.

Monitor: The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a CCP is under control.

Step: A point, procedure, operation or stage in the food chain including raw materials, from primary production to final consumption.

Validation: Obtaining evidence that the elements of the HACCP plan are effective.

Verification: The application of methods, procedures, tests and other evaluations, in addition to monitoring to determine compliance with the HACCP plan.

33. Entrepreneurship development through Business incubation

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Introduction

Fish is a source of valuable animal protein and is now considered a health food. This has resulted in increased consumer demand. Fish is now more expensive than meat and other animal foods. Being a highly perishable commodity, fish require immediate processing and various options are available for the value addition of fish. Fish processing, particularly seafood processing and marketing have become highly complex and competitive and exporters are trying to process more value added products to increase their profitability. Value can be added to fish and fishery products according to the requirements of different markets. These products range from live fish and shellfish to ready to serve convenience products. In general value-added food products are raw or pre-processed commodities whose value has been increased through the addition of ingredients or processes that make them more attractive to the buyer and/or more readily usable by the consumer. It is a production/marketing strategy driven by customer needs and perceptions.

According to the recent statistics, the annual capture and culture based fish production in India is around 90, 00000 MT. Seafood export sector is one of major foreign exchange earner in India. In 2015-16, India has exported 945892 MT of Seafood worth Rs.30, 420 crores. USA and South East Asia are continued to be the major importers of Indian seafood .Frozen Shrimp continued to be the major export item followed by frozen fish . Marketing of value added products is completely different from the traditional seafood trade. It is dynamic, sensitive, complex and very expensive. Market surveys, packaging and advertising are a few of the very important areas, which ultimately determine the successful marketing of a new product. Most of the market channels currently used is not suitable to trade value added products. A new appropriate channel would be the super market chains which procure directly from the source of supply of the products and control most of the components of production and supply chain like packaging, advertising and retail marketing. Appearance, packaging and display are all important factors leading to successful marketing of any new value added product. The retail pack must be clean, crisp and clear and make the contents appear attractive to the consumer. The consumer must be given confidence to experiment with a new product launched in the market. Packaging requirements change with product form, target group, market area, species used and so on. The packaging technology needs to be evolved which should be attractive, convenient and adding to the shelf life of the processed products.

Technology 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. A large number of value added and diversified products both for export and internal market based on fish, shrimp, lobster, squid, cuttlefish, bivalves etc. have been

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identified. However, the commercialisation of fish products still pose lot of challenges to the entrepreneur and researcher in terms of optimization of technologies and ultimately developing the technologies into a commercially viable business plan. In this regard, the Indian Council of Agricultural Research (ICAR) has started a Business Incubation Unit at the Central Institute of Fisheries Technology (CIFT) exclusively for the Fisheries sector through the World Bank funded National Agricultural Innovation Project (NAIP). It is designed to accelerate the growth and success of entrepreneurial start-up efforts through the mobilization of an array of business resources and services. Later in 2016 an Agri-Business Incubation Centre (ABI) was established in CIFT under the XII plan scheme of National Agriculture Innovation Fund (NAIF) of ICAR. The role of the ABI Centre is to facilitate the innovator and the researcher to turn their ideas into commercial ventures with focus on incubation and business development programme, including entrepreneurship, skill development and Grassroot innovators activities.

Health benefits of fish

As a rich source of nutrients, fish provide a good balance of protein, vitamins and minerals, and a relatively low caloric content. In addition fish are excellent sources of Omega-3 polyunsaturated fatty acids which appear to have beneficial effects in reducing the risk of cardio- vascular diseases and are linked with positive benefits in many other pathological conditions particularly, certain types of cancer and arthritis.

Fish represents an excellent option as a major source of nutrients. On a unit caloric basis fish can provide a broad range of nutrients. A high intake of fish is compatible with a reduction of both calorie and saturated fatty acid intakes. Coronary heart disease, hypertension, cancer, obesity, iron deficiency, protein deficiency, osteoporosis and arthritis are contemporary health problems for which fish provide a number of nutritional advantages and some therapeutic benefits. Nutritional factors of importance are calories, proteins, lipids, cholesterol, minerals and vitamins.

Conventional finfish and fishes potentially provide from 100 to 200 kcal/100g, which is mainly attributed to the protein and fat contents of fish. The amount of carbohydrates in fish is very small. Finfish usually contains less than 1% carbohydrate whereas shellfish have very low fat content. Compared to other muscle food, they contribute very low fat calories to the average diet. For example, each gram of fish muscle provides only 0.05 – 0.2g of fat compared to 0.25 – 0.5 fat per gram of red meat. The most important constituent of fish muscle is protein. The protein content in fish varies from 17 to 25%, though values as low as 9% are sometimes encountered as in the case of Bombay Duck. Fish protein is highly digestible because of very low stroma protein and has an excellent spectrum of essential amino acids. Like milk, egg and mammalian meat proteins, fish protein has a high biological value. Cereal grains are usually low in lysine and/ or the sulfur containing amino acids, whereas fish protein is an excellent source of these amino acids. In diets based mainly on cereals, fish as a supplement can, therefore, raise the biological value significantly.

Fish oil contains primarily the Omega -3 series of fatty acids. The polyunsaturated components of fish lipids can be effective in reducing plasma lipids. Epidemiological data from Japan and the Netherlands indicate that frequent consumption of fish even in quantities as low as 30g/ day may have beneficial effects in reducing heart disease. Consumption of medium (100g) to large amounts especially triglycerides, prevent thrombosis and ameliorate ischemic heart disease. These effects are mediated by the Omega -3 PUFA of fish lipids which alter the production of certain biologically important components called eicosanoid. The efficiency of the Omega -3 PUFA components is influenced by the amount ingested and the concentration of other unsaturated fatty acids in the diet, especially Omega -6 PUFA. Squalene, an isoprenoid molecule present in shark liver oil in higher quantities, has been reported to possess antilipidemic, antioxidant and membrane stabilizing properties. Fish and shellfish, particularly anchovies, clams, oysters and sardines are rich sources of vitamin B

Fish consumption is compatible with optimum dietary practices / recommendations and that substitution of fish for other foods can help to maintain a balanced nutrient intake compatible with a low fat consumption. In addition, the consumption of fish- or more precisely, fish lipids – may provide significant health benefits.

Entrepreneurship Initiatives in Fisheries Sector

Fisheries sector with its important role played in the socio-economic development of the country has become a powerful income and employment generator, and stimulates the growth of a number of subsidiary small, medium and large-scale industries. In order to translate the research results arising from the field of fisheries and other agricultural sectors, ICAR have set up an innovation-based Business Incubation Centre (BIC) at the ICAR-Central Institute of Fisheries Technology (CIFT), Cochin. BIC is managed by Zonal Technology Management – Business Planning and Development (ZTM-BPD) Unit and aims at establishment of food business enterprises through IPR enabled ICAR technologies.

BIC supports operations on business projects as a measure of enhancing the foundation for new technology-based industries and establishing a knowledge-based economy. It focuses on finding new ways of doing business in fisheries and allied agricultural fields by finding doors to unexplored markets. The Centre helps prospective entrepreneurs, by providing pro-active and value-added business support in terms of technical consultancy, infrastructure facility, experts' guidance and training to develop technology based business ideas and establish sustainable enterprises. It acts as a platform for the speedy commercialization of the ICAR technologies, through an interfacing and networking mechanism between research institutions, industries and financial institutions. The Incubator at ICAR-CIFT differs from traditional Business Incubators as it is tailored specifically for technology based industries and is operational at an area with a high concentration of fish production. This industry-specific incubator also allows new firms to tap into local knowledge and business networks that are already in place. BIC offers their services to industries not only in Cochin, but also all over India through virtual incubation. Beyond promoting business growth, the Centre is also trying to bring its benefits to all the fisheries communities in India.

This unique Business Incubator is now known as a "One Stop Shop", where entrepreneurs can receive pro-active, value-added support in terms of technical consultancy, and access to critical tools such as entrepreneur ready technologies, vast infrastructure and other resources that may otherwise be unaffordable, inaccessible or unknown. With the aim of transforming the incubator into a symbol of entrepreneurship and innovation, the ZTM-BPD Unit has created an environment for accessing timely scientific and technical assistance and support required for establishment of technology based business ventures. The activities of the ZTM-BPD Unit focuses on finding creative and innovative ways for linking public sector resources and private sector initiatives within and across regional and national boundaries for promoting economic growth. The Centre uses the right expertise in relevant fields to identify and analyze the constraints and barriers hindering the growth of a business, and devise appropriate strategies. It explores the various structures and strategies to help small enterprises to grow and ensure a promising future in the global market. It fosters corporate and community collaborative efforts, while nurturing positive government-research-business relationships.

Process of Incubation

The Business Incubation Centre targets entrepreneurs, from fledgling start-ups in need of basic small scale processing capacity to sophisticated businesses in need of R&D back up, office infrastructure and pilot / test market processing facility for the development of new products. It possesses good infrastructure facilities suitable for providing direct incubation of nine entrepreneurs in a corporate environment within the premises of ICAR-CIFT, at a time. The purpose of direct incubation is to support emerging companies through their infancy. BIC apart from being a multi-tenant facility with on-site management that delivers an array of entrepreneurial services to clients operating with the facility, it also serves clients that are not located in the facility through virtual incubation or incubation without walls.

The Centre regularly conducts industry interface and technology promotional programmes for sensitization of entrepreneurs and to identify interested potential candidates for physical and virtual incubation. The Clients at BIC gets the privilege of meeting Scientists, Business Manager and Business Associates directly, to discuss and finalise the strategies to be adopted to take the business forward. It is also the peer-to-peer relationships that develop within the incubator, that ensures the delivery of basic services such as how to actually incorporate a business; what are the legal issues; how to take intellectual property protection; how to do basic accounting and cash flow; how to do business presentations etc. Those kinds of skills are what are transmitted as part of the incubation process.

The residency period for direct incubatees is normally for two years, extendable by another year in special cases, depending on the progress of incubation. As the business venture becomes mature enough, the concessions and the facilities provided to the incubatee companies will be gradually withdrawn. Each incubatee of the Unit will have to pay to the Institute a charge for utilization of space, at a rate concessional to the benchmark rate which is the prevailing market rent realizable. Incubatee mentoring will continue in virtual mode after graduation, on need basis.

Services and facilities offered by ICAR-CIFT Business Incubator

The Centre through its business support services provides links to supporting industries; upgrade technical / managerial skills; provide scientific / technical know-how; assist in market analysis, brand creation and initial test marketing; protect IP assets; and find potential investors and strategic partners.

Incubation facilities under one roof are:

- Furnished office suites within the premises of ICAR-CIFT, with shared facilities like secretarial assistance, computing, copying, conferencing, video conferencing, broad band internet and communication services.
- Pilot level production lines
- Culinary facility
- Access to modern laboratory facilities for product testing and quality control
- Access to well-equipped physical and digital libraries

Pilot Level Production Lines

A state-of-the-art generic semi-commercial production facility is made available to incubating entrepreneurs for developing value added products from fish . BIC provides access to these facilities along with support of manpower, and assists the entrepreneurs in production and testing of new product formulations. For the tenants, the pilot plant is an ideal testing arena to determine the commercial viability of new products. The plant also serves as a process lab, a place to see how processing equipment impacts food products under varying conditions. There are production lines for pre-processing, cooking, retort pouch processing, canning, sausage production, extruded products, chitin & chitosan, smoking, curing & drying, breading & battering and product packaging. By providing access to these resources, the Centre greatly reduces one of the major barriers to the commercialization of institute technologies by smaller firms - the high capital cost of intermediate or large scale process equipment.

Business Services

The business oriented services offered by BIC include assistance in complying with business regulations and licensing procedures, financing, information services, marketing, and tailor-made services designed for the various tenant enterprises. Incubator clients can also gain special advantage in terms of tax savings through special regulations for Business Incubators. BIC also offers a wide variety of services, with the help of strong associations throughout the Business Incubation Network

Conclusion

Fish processing and value addition has evolved over the years as the sunrise sector in Agriculture domain. Globally many new species are being introduced in the Aquaculture sector. A comprehensive study on the suitability of these species for value addition has to be carried out to propose optimized utilization protocols. Functional fish products will be in much demand in future; the challenge will be to retain the functional benefits of fish & shellfish meat by way of adopting product specific processing protocols or alternate delivery systems for sensitive components. These issues offer ample scope for Innovation coupled with entrepreneurial skills for the creation of wealth and employment in fisheries sector.

34. Regulations of EU for import of fish and fish products

S. S. Das[1]

Export Inspection Council (EIC)

- Regulatory Authority under the Department of Commerce, in the Ministry of Commerce & Industry, Govt of India.
- The Official Export Inspection & Certification Body of India
- Established in 1964 by Govt. of India under section 3 of Export (Quality Control & Inspection) Act, 1963

Objective

- To ensure sound development of export trade of India through quality control and pre-shipment inspection
- Export Inspection Agency – Field offices of EIC

Powers conferred under Act

Notify the commodities - compulsory pre-shipment inspection (Mainly based on risk assessment/foreign rejection)

Establish the type of quality control/ inspection that will be applied to such commodities (CWI/FSMS)

Establish/recognize specifications for the commodity

To prohibit the export of the notified commodity unless it satisfies the conditions relating to quality control

EU Laws

Regulation

It is a binding legislative act. It must be applied in its entirety across the EU. In general, Council adopted a regulation when EU wanted to make sure that there are common safeguards on goods imported from 3rd countries.

Directives

It is a legislative act that sets out a goal that all EU countries must achieve. However, it is up to the individual countries to devise their own laws on how to reach these goals.

Decisions

It is binding on those to whom it is addressed for a specific case and for specific country.

EU food safety policy

Four main areas of protection

- **Food hygiene:** food businesses (farms to restaurants) must comply with EU food laws including those imported to EU.
- **Animal health:** sanitary controls and measures for pets, farmed animals and wildlife to monitor and manage diseases, and trace the movement of all farm animals.

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- **Plant health:** detection and eradication of pests at an early stage prevents spreading and ensures healthy seeds.

Contaminants and residues:

monitoring keeps contaminants away from food and animal feed. Maximum acceptable limits apply to domestic and imported food and feed products.

TRACES is the European Commission's online platform for sanitary and phytosanitary certification required for the importation of animals, animal products, food and feed of non-animal origin and plants into the European Union, and the intra-EU trade and EU exports of animals and certain animal products

Categories of products

- Products intended for human consumption (HC)
- Products intended for non-human consumption (NHC)
- Live animals, semen, ova, embryos

General condition for import to EU

- The country is authorized to export
- The CA is recognised (Administrative power to exercice control on FBO and implement of RMP)
- The establishment has been approved (approved by CA and enlisted in the EU site)
- Introduction into the EC via an approved BIP for veterinary checks.
- Consignment notified in advance
- Common VeterinaryEntry Documents (CVED)
- Original Sanitary documents (fax/copy not accepted)

Regulation No 178/2002/EC

- Known as the regulation on general food law
- Strengthens the rules on the safety of food & feed in EU.
- Sets up the European Food Safety Authority (EFSA), which provides support for the scientific testing and evaluation of food and feed.
- It applies at all stages of the food chain (production, processing, transport and distribution)
- The regulation does not cover production on the farm for private use or the handling of food at home.

KEY POINTS of 178/2002/EC

- Foods dangerous to health or unfit for consumption shall not be put for sale.
- If any part of a batch is found unsafe, then it is assumed that the whole batch of food or feed is considered unsafe.
- Information to be provided to the consumer:
- The normal conditions under which food is used by the consumer
- if intended for a specific category of consumers.

Role of FBO:

- Guarantee the traceability of food, feed and food- producing animals at all stages of production and distribution.
- Immediately withdraw food or feed from the market or recall products already supplied, if these are considered to be harmful to health,
- Inform the appropriate authorities and consumers where necessary.

Role of EFSA:

- Provides scientific and technical support on food safety
- Responsible for coordinating risk assessments, identifying emerging risks and advising on crisis management.
- If risk is identified, EU countries and the Commission may adopt provisional precautionary measures consistent with a high level of health protection.

Rapid Alert System for Food and Feed (RASFF)

- Measures to restrict the circulation of food/its withdrawal from the market/ impose specific conditions on the placing on the market.
- This information is made available to the general public where appropriate.
- Commission's emergency protective measures like suspending imports to EU, if food or feed presents a serious health risk.

Regulation 2019/1381/EC

- Transparency and sustainability of the EU risk assessment in the food chain amends mainly Regulation (EC) No 178/2002.
- Ensure more transparency:
- The public will have automatic access to all studies and information in support of risk assessment.
- Develop comprehensive risk communication:
- Ensure a comprehensive risk communication throughout the risk-analysis process, combined with open dialogue amongst all interested parties, verification for serious controversies
- /conflicting results, fact-finding missions to verify the compliance of laboratories, presenting overview report on outcome of the fact-finding missions etc.

852/2004/EC

- Ensure the hygiene of food at all stages of the production process, from the primary production stage (farming/fishing) to the final consumer.
- FBO (other than farming or fishing) shall implement HACCP.
- Where required by national or EU legislation, businesses in the food sector must be approved and all premises registered with the appropriate authority.
- This EU law does not cover issues relating to nutrition, composition or quality, or the production or preparation of food in the home.

Annex I:

- covers hygiene requirement for the activities of primary production (i.e. farming/fishing), including transport, handling and storage of primary products and the transport of live animals.

Annex II:

- covers hygiene requirement of food premises and equipment, transport conditions, food waste, water supply, personal hygiene and training of food workers, wrapping and packaging, heat treatment processes etc.
- In addition, FBO must comply with the hygiene requirements of 853/2004/EC for foods of animal origin.
- Food imported into the EU must comply with EU standards or their equivalent and the requirements of the importing country if any.
- Traceability rules, introduced under Regulation (EC) No 178/2002, also apply to food imported into EU.
- Where a firm in the food sector discovers that a food presents a serious risk to health, it must immediately withdraw that food from the market, informing users and the relevant authority.

853/2004/EC

- Lays down specific hygiene rules for FBOs of food of animal origin both for processed and unprocessed.
- Aims to ensure a high level of food safety and public health.
- European Union (EU) countries must register and, where necessary, approve establishments handling products of animal origin.
- Rules are applied to all the steps of pre-processing & processing
- e.g. Slaughterhouses/cutting and boning, storage, transport and maturation.
- Fishery sectors: harvesting, equipment, facilities, processing and transport.

2073/2005/EC

- Microbiological criteria for foodstuffs with respect to the general and specific hygiene requirements as per 852/2004/EC on the hygiene of foodstuffs.
- Provide objectives and reference points to assist FBO and CA to manage and monitor the safety of food.
- FBO to ensure that the food they handle, supply or process complies with two criteria.
- food safety criteria
- process hygiene criteria.
- It specify which micro-organisms to be tested, sampling plan and analytical method etc.

315/93/EC

- Protect public health by prohibiting the marketing of foods
- containing an unacceptable amount of contaminants
- Contaminants are present in food as a result of treatment after production or through

environmental contamination.
- The EU regulates the toxicologically acceptable levels of contaminants and keeps them at the lowest possible levels.
- Must not prohibit trade of foods that comply with this regulation.
- Extraneous matter, such as insect fragments, animal hair, etc. are not covered by this regulation.

1881/2006/EC

- Sets maximum levels for certain contaminants in food that have not been intentionally added to food but have arrived in the course of its production, packaging, transport, etc.
- Food with higher level of contaminants as specified shall not be sold.
- These limits cover the edible part of food.
- Foods complying with the maximum limits may not be mixed with other foods which exceed these limits.

183/2005/EC

- Requirements for feed hygiene:
- Ensures that feed safety.
- Ensure that animal feed is safe and of good quality by ensuring its traceability throughout the entire animal feed chain.
- Applies to the activities of feed business operators including feeding of food-producing animals for export.
- Excludes feeding of food-producing animals kept for private domestic consumption.

Main elements of 183/2005/EC:

- Compulsory registration of all feed business operators by CA.
- Approval of feed additives, pre-mixtures and compound feeding stuffs.
- Good hygiene practice to be applied at all levels of production and use of feed.
- Introduction of the HACCP principles for the production.

1169/2011/EC

Labeling of foodstuffs

- Ensures appropriate food information to the consumers
- It merges the previous legislation, Directives 2000/13/EC on the labelling of foodstuffs and 90/496/EC on nutritional labeling.
- Responsibility lies with the manufacturer and the importer.
- Mandatory information includes food's name, list of ingredients, net quantity, use by date, instructions for use if applicable, operator's name and address and a nutrition declaration.

2017/625/EC

- Official controls to ensure that food and feed laws are enforced to protect human health, animal health & welfare and plant health.

- Sets out a risk-based official control system by the to ensure food safety/integrity/ wholesomeness is maintained throughout production, processing and distribution.
- Sampling, analysis and testing for samples taken during official control activities
- Enforcement action in the event of non-compliance
- Training of staff of the CA and other related authorities.

Some important EU regulations

2021/405/EC :

- Lists of third countries authorized for export to EU

2020/466/EC :

- Temporary measures to contain risks to human, animal and animal welfare due to coronavirus disease.

2020/2235/EC:

- Model official certificates for the entry into the EU and movements within the EU.

2019/1014/EC:

- Detailed rules on minimum requirements for BIP.

2019/1871/EC:

- Set reference point for action (RPA) for the prohibited substances not having MRL as per 37/2010/EC.
- Non-complied food shall not enter into EU.

2019/624/EC :

- Specific rules for the performance of official controls on the production of meat and for production and relaying areas of live bivalve.

2016/429/EC:

- The competent authority shall include the certain information in the register of aquaculture establishments

396/2005/EC:

- Maximum residue levels of pesticides in food and feed

35. Disruptive extension for effective technology dissemination in Fisheries

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Food and nutritional security have now become a global concern with the increasing trend of population growth. Aquaculture is considered as a promising food production sector for providing high quality affordable protein food for sustaining the nutritionally secured livelihood of millions of rural populaces. Despite the significant contributions of the sunrise sector, global debates on fisheries issues and policies appear to be dominated by different degrees of concerns over environmental sustainability, overfishing and overcapacity in the fishing domain and in the post- harvest front, the processing industries face multifarious problems like complicated exporting procedures, high shipping costs, cut-throat competition in the industry, changing quality standards of importing countries, irregularity in supply of raw materials, hygiene problems and non-availability of quick transportation facilities from the fishing port to the processing units, etc. As a result of which trade-driven commercial fish farming is suffered that reduces the livelihood opportunities of small-scale dry fish processors, petty traders within the communities of poor fishermen.

Small-scale fisheries are normally characterized by low capital input activities, low capital intensive, 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. Likewise, there are multitude of challenges associated with the socio-economic fabrics of the sector, which needs adequate attention from the social scientists to understand and put necessary effort to prove the sunrise sector as a potential driver of economic development. Technologies are the main drivers of growth. Hence, systematic technological interventions backed up 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 which can bring a change in the performance of the sector. Keeping eye upon this, following strategies have been suggested for an accelerated fishery development with

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focus on poverty alleviation of poor fishers:

- ❖ Commodity-centered approach
- ❖ System approach
- ❖ Prioritize technology on the basis of needs and problems at micro and macro levels
- ❖ Skill development/upgradation of the fishers
- ❖ Monitoring the technology demonstrations programs and assess the impacts.
- ❖ Innovate and strengthen institutions and policies
- ❖ Enhance investment and reorient policies to facilitate percolation of benefits to all sections of the society.
- ❖ Follow ecological principles
- ❖ Emphasize on domestic market demand and consumers' preferences
- ❖ Strengthen database and share it for a better planning and policy making in the sector.

Extension systems for sustainable development

Unlike India, the economy of developing and underdeveloped countries in sub Saharan Africa, Latin America, Asia inclusive of 22 Low Income Food Deficit Countries (LIFDCs) is predominantly agrarian economy, where agriculture inclusive of fisheries provides employment and livelihood to majority of the rural households, but the condition of both farmers/fishers and farming is in alarming state.

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.

As per the report of world commission on Environment and Development (1987), sustainable development meets the needs of the present generation without compromising the ability of future generation to meet their requirements. The FAO committee on Fisheries (1991) defines sustainable development more elaborately as the management and conservation of national resource base and the orientation of technological and institutional intervention to ensure the attainment of human needs for present and future generation including fulfilment of social and economic demands and conserving the natural resource base. In response to that FAO developed a code of conduct for Responsible Fisheries (FAO,1995) that provides principles and guidelines for ensuring sustainable exploitation of marine resources. Sustainable fisheries can be possible through responsible fishery, which envisages rational fishery management that address a range of issues dealing with resource status, environmental health, post-harvest technology, trade and export, socio-economic benefits, legal and administrative support. Sustainable agricultural systems must be resource-conserving, socially supportive, commercially competitive, and environmentally sound. Hence, the agriculture research system must place emphasis on generation of resource conservation technology (RCT) along with strong forward-backward linkage between research-extension system. It involves design and management procedures that work with natural processes to conserve all resources, promote ecosystem resilience and self-regulation, minimize waste and environmental damage, while maintaining or improving farm productivity and profitability (MacRae et al., 1990).

The role of extension in 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.

Further, with the advent of global competitiveness and market liberalization, our prevailing extension system has to be strengthened with innovative extension approaches to tackle the recent challenges in fisheries *viz.*, climate change, weather aberrations, dwindling resources and quality and safety of products; so that fishers can adjust their production portfolio keeping eye upon the emerging trends in food consumerism in domestic as well as global markets. Grooming fishers with proper information support for taking right decision related to fish production essentially requires a strong network of extension systems, supported with government initiatives and strong linkage among extension scientists and functionaries working for fishery sector development. This would ensure the livelihood security of millions of fisher communities by improving the quality production and creating better job opportunities, which intends to bring out planned changes to meet the needs of the present generation without compromising the future generation's requirements.

Innovative extension approaches for technology dissemination in fisheries

Earlier in developing countries, the extension personnel were involved in diffusion of farm technologies generated by public research organizations, mostly disseminated through appropriate mechanism, viz., On Farm Trials (OFT), frontline demonstrations (FLD), field visits, fishers' meetings, media use, etc. This process had the conceptual backup from the ‘diffusion of innovation’ model. But in the last two decades, the paradigm shifts in development pivots to the enhanced concern for future generations to meet their basic needs, accordingly the nature, design and integration of fisheries technologies are drawing attention of the extension professionals and practitioners across the globe. In India, different models for transfer of technology have been tested and some robust extension approaches have been validated. Furthermore, the frontline extension system of the country has been revisited and sharpened through fishers-oriented approaches for technology adaptation and dissemination. The extension system in India has been designed to move beyond technology and beyond commodity through reciprocal fishers-research-extension linkages. Fish farmers still suffer from lack of access to appropriate services like credit, inputs, market, extension, technologies etc. Keeping eye upon this, the World Development Report has focused on need to restructure and revamp agricultural extension system as a tool for realizing the growth potential of farm sector against the widening demand–supply pressures for ensuring sustainable fisheries, inclusive, pro-poor socio-economic development. 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. Extension approaches have to be redefined depending upon the components involved for sustainable growth and livelihood security of the farmers for which a conceptual framework has to be developed in response to recognizing and considering different livelihood assets viz., *human, social, physical, natural and financial resources*. Some of the following innovative extension approaches originating from multiple sources must be adopted on trial basis to make fisheries more lucrative and sustainable which can be replicated in the fishery sector interwoven with numerous challenges like increased production with sustained natural resources, growing market demand for processed products having entrepreneurial opportunities, protection and conservation of environment, and promoting international trade.

An analysis of national extension systems in the Asia and Pacific region by Qamar (2006) observes that agricultural extension is undergoing a major transformation as a result of failure of public extension systems perceived to be outdated in the context of globalization, decentralization, and information technology revolution. Extension systems in many developing countries are undergoing a paradigm shift to more fishers -oriented approaches based on rural innovation that emphasize the importance of interactive, integrated and multidisciplinary oriented mutual learning between formal and informal knowledge systems (Friederichsen, 2009).

a. Asset Based Community Development (ABCD) approach

As per the traditional approach to development, poor people see themselves as people with special needs that can only be met by outside supporting agencies. But Asset Based Community Development (ABCD) approach intends for the development of community based on the principle of identifying and mobilizing individual and community ‘assets’, rather than focusing on problems and needs. It is an extension approach in which a community's micro-assets are linked with its macro environment. It believes that communities can initiate and sustain the process of growth and development themselves by recognizing and harnessing the existing, but often unrecognized assets, and thereby promoting local economic potential to drive its development process (Rans & Green, 2005). The approach is optimistic in nature, because the focus is on *'what is possessed by the community, rather than the problems of the community."*

The focal point in this approach is asset and not the need of the community. Assets of individuals, associations and institutions are identified after an extensive survey and assets are then matched with the need of the people to empower communities to control their futures and create tangible resources such as services, funds and infrastructures etc. *(Foot and Hopkins, 2010.* In 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 providing their livelihoods by developing their technical, organizational and management skills and practices (GFRAS, 2011; FAO, 2010). RAS designers and implementers must recognize the diversity of actors in extension and advisory fields (public, private, civil society); the need for extending support to farmers' producer organizations (FPO) and rural communities (beyond technology and information sharing) including advice related to farm, organizational and business management; and explaining the role of facilitation and brokerage in rural development and value chains. In the case of aquaculture, large-, medium- and small-scale 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 disseminating information to fishers. In this direction, innovative 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 FPOs to ensure coordinated support to fishers.
- ⇨ Exploiting information communication technologies (ICTs) to provide fishers with a range of information related to weather, prices, extension programmes and generic information regarding fisheries.
- ⇨ Facilitating the formation of FPOs and also collaborate with FPOs to strengthen the demand and supply side of RAS.
- ⇨ Promoting institutional and policy change to enable and support small-scale fishery.

RAS encourages the formation/ organisation of groups by involving individual 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 and make their voice heard. Such groupings can act as platforms to articulate concerns, exchange knowledge, influence policies and engage in collective action so that their agriculture remains sustainable and profitable. Effective formation of Rural Resource Centres (RRCs), Fishermen Cooperative Society, Farmers producers Organisations (FPOs) can be instrumental by galvanizing collective action in order to ensure better access to markets and to support innovation by their members in related activities (Sundaram, 2014).

c. Model Village System of Extension (MVSE) approach

MVSE is an integrated and holistic extension approach where *community participation* 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 various 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 experimentation fishers will eventually "own" and adopt improved practices by themselves side-lining 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 method. Farmer Field School (FFS) model has been accepted as a good methodology because it is exclusively participatory. A special feature of this extension approach was that it reached poor and female-headed households and lower-caste households much better than the regular extension services (Tiwari et al. 2010). 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 agricultural goods. Thus, revamping the extension system will have a catalytic role for ushering in farmer-led and market-led extension; which can subsequently alleviate poverty and ensure livelihood security. In the light of this, the challenge remains to motivate the extension personnel to learn the new knowledge and skills of marketing before assigning them marketing extension jobs to establish their credibility and facilitate significant profits for the 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 IT application in agriculture will bring remarkable change in the attitude and knowledge level of user. Basic requirement is to provide most appropriate information in such a capsule that can be easily understood and used by them. This approach will strengthen the extension system for better dissemination of technology. As a case study the contribution of Digital Green, a NGO that uses an innovative digital platform for community engagement to improve lives of rural communities across South Asia and Sub-Saharan Africa is remarkable. Digital Green associate with local public, private and civil society organizations to share knowledge on improved farmers practices, livelihoods, health, and nutrition, using locally produced videos and human mediated dissemination. As per the study, the Digital Green project (participatory digital video for agricultural extension) increased the adoption of certain farm practices seven times higher compared to traditional extension services and the approach was found to be 10 times more cost-effective per dollar spent. Hence, along with ICT-based advisory services, input supply and technology testing need to be integrated for greater impact and content aggregation from different sources require to be sorted in granular format and customized in local language for rapid adoption of technologies (Balaji et al., 2007&Glendenning and Ficarelli, 2011).

The effectiveness of this innovative extension approach depends on capacity building, people's participation along with government initiative to provide strong infrastructure to be worked with the cutting-edge technologies. The farmer friendly technology dissemination process needs to be handled with careful planning by the incorporation of information communication technology. The use of ICT application can enhance opportunities to touch the remote farmers to live in close proximity of the scientific input. The computer based web portals namely aAQUA, KISSAN Kerala, TNAU AGRITECH Portal, AGRISNET, DACNET, e-Krishi, ASHA, India Development Gateway (InDG) portal, Rice Knowledge Management Portal (RKMP), Agropedia, KIRAN, AGMARKNET, ITC-e-Choupal, Indiancommodities.com, Mahindra Kisan Mitra, IFFCO Agri-Portal, Agrowatch Portal,

iKissan, etc. along with some mobile based Apps like mKRISHI® Fisheries, riceXpert, Pusa Krishi, Krishikosh, m4agriNEI 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 approach:

Recently, a new extension approach christened as 'disruptive extension' comes into limelight which is considered as an innovative extension approach that creates a new paradigm of extension that eventually disrupts an existing approach followed by extension professionals in the field of agriculture and allied sectors. It is an entrepreneurial oriented sustainable extension system that can able to transform every link in the food chain, from farm to fork. It is a cost-recovery extension approach the fulcrum of which lies between resource exploitation on one side and resource conservation on another side that influence the livelihood security and technology sustainability for small scale farm holders. It deals with the following principles:

- Importance of good governance in agriculture (and allied fields) that considers the resource rights of the farmers.
- Emphasis on growing interest among the stakeholders by explicit analysis of field level issues for technology adoption.
- Potential to resolve the social conflicts for equal access to community resources through Memorandum of Understanding (MOU).
- Based on cost recovery mechanism.
- Ensure commitment to optimum resource management and maximum economic benefit to improve food security.
- Provision of community based social insurance.
- Maintaining the sustenance of the technology supports through custom hiring approach.
- Focus on pluralistic convergence of different partners to build a network of linkage with various entities around the farm households.
- Encouraging the farmers-scientist interaction for technology development, assessment and application through Farmers' FIRST approach.

Global agriculture embraces diverse actors in its endeavour to feed about 10 billion people in the planet by the end of 2050. The small, marginal & landless farmers are extremely vital for food security due to shrinking of resource day by day. The contribution of women 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 agriculture extension is the key to address the growing challenges, which need to be validated, integrated and scaled up and further recommended for large scale implementation by the policy makers. The innovative extension approach should be based on capacity building, skill development, people's participation along with government initiative to provide policy support to be worked 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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36. Assessment of harvest and post-harvest losses in fisheries value chain

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Introduction

Indian fisheries and aquaculture is an important sector of food production, providing nutritional security to the food basket, contributing to the agricultural exports and engaging about fourteen million people in different activities. The total fish landing during 2018 was 34.9 lakh tons worth approximately Rs.57,510 crores. India's marine product exports was 13.77 lakh tons earning 7.08 US billion dollars during 2017-18 which underlines the importance of the sector. Studies have pointed out that considerable harvest and post-harvest losses occur all along the fishery value chain through the various channels of distribution. Huge losses occur along the fish value chain, both in terms of quantity and quality due to discards at sea, improper handling, storage & icing, lack of cold chain facilities and delay in transportation. Reducing harvest and post-harvest fish loss will enable money saving for the primary producer, enable the sector to feed more and ease the pressure on water, land and climate. Ensuring proper cold storage facilities along the value chain, climate smart processing and packaging, value addition, technology interventions in transportation to avert spoilage can bring down post-harvest losses from 10 to 50% in the fisheries sector. The inland fisheries covers the brackish and freshwater systems with aquaculture practiced and managed in ponds and fields connected to natural resources. The fish landing sites are numerous and remote in interior parts of the country sometimes inaccessible. Delay in transport, non-availability of ice for proper storage brings down the price of freshwater fishes in the markets which is an economic loss for the primary producer.

The resources once harvested has to be managed and utilized judiciously to derive the maximum benefit and sustain the livelihoods of lakhs of stakeholders involved along the fishery value chain. For an assessment of the extent of harvest and post-harvest losses in marine and inland fisheries at the National level, sound statistical estimates have to be computed. The changes in fisheries sector with reference to technology advancements have led to a changed definition of 'losses' which has been accepted by researchers worldwide. Therefore, assessment of harvest and post-harvest losses gains importance when formulating effective strategies for wholesome utilization of fish and fish products.

Fish losses

Loss per se is defined as the quantity of marine fish which is not fit for human consumption due to physical loss or spoilage of some other reason. Losses at the time of harvesting and onboard the fishing craft are called harvest losses and losses occurring after harvesting *i.e.* from the landing centre up to the consumer at different stages are called post-harvest losses. Literature

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classifies Post-harvest losses broadly into three categories –

- ✓ Physical loss
- ✓ Quality loss
- ✓ Market forced loss

Post harvest losses occur due to improper handling and lack of infrastructure at different points starting from the landing centre to the consumer. Apart from these, there are latent losses such as realization of low value due to glut, multi-day fishing etc. Discarding takes place because, in the course of fishing, many species other than the target species are often caught. This by-catch is usually discarded at sea unless it is worth keeping. Discarding by-catch consisting of a small proportion of mature specimens from healthy stocks causes relatively little damage, but when it consists of juveniles of commercial species it will disturb the balance of the system. Catching large numbers of juveniles is likely to reduce the future number of mature fish. This will have a direct impact on the fishery taking the by-catch, or on other fisheries if the juveniles belong to their target species.

Apart from the loss of a massive amount of potentially valuable food, the incidental capture of dolphins in tuna purse seine nets, turtles in shrimp trawls and marine mammals, birds, turtles and fish in high-seas squid driftnets has led to widespread public concern. Unfortunately, by-catches are an inevitable consequence of an industry that depends upon the capture of species that live alongside other creatures in an opaque medium and as a result can seldom be directly observed and targeted.

By-catch arises primarily because of fishing gears and adopting practices which do not selectively target the desired size and species. The reason for discarding part of the catch is generally economic. In such cases the cost of bringing fish to market is greater than its market value and it gets dumped at sea. Similarly, where a fishing vessel has limited holding capacity, low-value species are discarded in favour of the high-value ones. Introduction of improved harvesting methods, starting from mechanization, indiscriminate increase in fleet size and number, multi-day fishing, use of unregulated mesh sizes have all led to imbalance in several forms and threatening of food security. In tropical countries, high temperatures lead to fish spoilage while still in the boat, at landing, during storage or processing, on the way to market and while waiting to be sold. There is also considerable economic loss as value gets lost because of lower quality, including insect infestation and breakage.

Several studies have been conducted in the recent past for the assessment of extent of harvest and post-harvest losses in fisheries. As early as 1981 FAO recommended action to reduce post harvest losses in marine fisheries- estimated at that time to be 10 percent of the global total, and up to 40 percent in some developing countries. Studies were conducted at CIFT, Cochin on ‘Assessment of harvest and post-harvest losses in fisheries’ through a NATP funded project . The percentage loss due to harvest through traditional, motorized, mechanized and large trawlers has been put at 4.13, 3.61, 14.48 and 21.41 respectively within the craft/gear (Anon., 2005). The study has also assessed post-harvest losses in fisheries in different channels viz., market, pre-processing and processing and reported the percentage loss through each of these channels. Losses can be physical, economical and nutritional and can be minimized by adopting suitable post-harvest technology (Johnson and Ndimela, 2011).

Ahmed (2008) has assessed post-harvest losses of fish in Sudan with special emphasis on cultural and socioeconomic aspects including traditional food conservation; economic factors for food conservation and cost-benefit; assessment of the effect of globalization and liberalization of food markets and the fish trade in artisanal fisheries. Ward, A. (1996) developed methods to quantitatively assess post harvest fish losses and to understand and identify the causes in qualitative sense. Adams, (1995) advocates Individual Fishing Quota (IFQ) system where fishermen can be selective about factors as fishing depth, bottom substrate, or time of day, month or year. These factors are directly related to incidental halibut by catch mortality. Clucas, et. al. (1989) reported 20% post harvest losses of annual fish production of about 13.5 lakh tonnes by 16 ECOWAS countries of West Africa. Similar figures were observed in the artisanal fisheries sector that contributes about 90% of the total catch.

Estimation of losses in fisheries

A recent study completed at CIFT, Cochin attempted to estimate harvest and post-harvest losses in marine fisheries. Ernakulam and Alleppey districts were covered for the study. The estimation was carried out at the two stages harvest and post-harvest stages using stratified random sampling design. The channels of fish production namely mechanised, motorised and traditional formed the various strata at the harvest stage, In the post havest stage, losses occurring at landing centre, processing, marketing and transportation sectors were observed. The study was conducted for a full fishing season to observe loss pattern during monsoon, pre-monsoon and post-monsoon seasons. Around 1 to 3% sampling was done in the harvest stage whereas for the post-harvest study, the samping done was from 10 to 30% for the various channels.

In the processing channel, the pre-processing centres and fish processing centres in Ernakulam and Alleppey district were covered by using of a sample. The losses occurring in marketing sector was studied in the wholesale markets, retail markets, roadside markets were covered for the study. The dryfish production and marketing channel was also studied by means of a sample for recording losses occurring in the dryfish sector. The estimates were computed using methodology derived by IASRI for loss estimation (Anon., 2005).

Harvest losses in marine fisheries was estimated from Ernakulam district by stratifying fishing crafts into mechanized, motorized and traditional. Primary data on fish catch and losses was collected for 12 months from fishing crafts operating in six selected fish landing centres at Ernakulam. Loss estimates were computed analyzing the season wise data and pooled data. The sector wise harvest loss estimates are as under :

Harvest losses

Sector	Pre-monsoon (%)	Post-monsoon (%)	Monsoon (%)	Overall (%)
Traditional	1.93 (0.43)	0.98 (0.37)	0.83 (0.28)	1.14 (0.28)
Motorised	3.45 (0.54)	2.76 (0.13)	4.38 (0.53)	3.65 (0.17)
Mechanised (upto 7 days fishing duration)	12.74 (1.23)	11.09 (0.11)	9.11 (0.05)	14.15 (2.10)
Mechanised (more than 7 days)	13.78 (1.24)	14.98 (1.35)	13.35 (1.32)	18.73 (2.22)

Multiday fishing by the mechanized trawlers reported maximum loss due to capture of juveniles and their discards. Around 1500 to 2750 kg of fish gets discarded at sea by trawlers during fishing trips for more than 7 days duration. The no. of hauls during fishing and loss was positively correlated (0.69) at 5% level of significance. The estimate of loss due to mechanized fishing was computed by utilizing information on no. of hauls which was more precise than the traditional estimator. The losses due to motorized fishing crafts was very less in comparison with trawlers. The traditional fisheries sector reported minimal or no loss during the period.

Post-harvest losses

The post-harvest losses in marine fisheries (at the landing centre level) was estimated as below :

Sector	Loss % (SE)
Traditional	0.09 (0.0004)
Motorised	1.19 (0.07)
Mechanised	4.79 (1.09)

The loss estimates when compared with the estimates brought out by earlier studies indicate that the post-harvest losses have come down due to efficient handling of catch. The post-harvest losses in processing and marketing sector was also computed from Ernakulam-Alleppey during the period under report. For reporting loss in processing sector, 50 pre-processing units and 25 processing units were observed and data on raw material processed and loss were recorded fortnightly. Shortage of ice and spoilage were cited as the reasons for loss in pre-processing. At the processing stage, losses occurred due to discolouration, broken tentacles, black spot and at time loss during glazing. Few units reported rejections at export destination due to heavy metal detection.

Losses in the marketing sector was due to damage during transportation, spoilage when delay in transport and weather. Two wholesale markets for fresh fish and one wholesale market for dry fish were covered fortnightly for recording losses due to marketing. Similarly 4 retail markets were surveyed fortnightly of reporting loss in retailing fish. The estimates for post-harvest losses due in processing and marketing are given below :

Post-harvest losses in marine fisheries

Sector	Loss % (SE)
Pre-processing	0.38 (0.04)
Processing	1.19 (0.07)
Dry fish production	36.97 (12.88)
Wholesale market (fresh)	3.79 (1.09)
Wholesale market (Dry)	7.56 (2.12)
Retail market (fresh)	3.13 (0.02)
Retail market (Dry)	8.23 (0.13)
Roadside market (fresh)	2.54 (0.11)
Roadside market (dry)	5.43 (1.19)

The reasons for losses were also recorded along with the loss details. Harvest losses were mainly due to i) Fish fall from net ii)Bruising due to handling iii) Fish spends too long in the net and gets spoiled iv) Lack of ice / Chilling causing spoilage

The reasons for post-harvest losses -

At landing centre the post harvest losses occurred while (i) loading for transport, (ii) kept in the beach without sufficient ice. During the processing of fish when there is a low capacity in the plant fish procured for processing gets spoiled leading to losses. Also adverse weather conditions while drying and insect infestation lead to post-harvest losses

The reasons for post-harvest losses during transport, storage and marketing are listed as under

Transport

i) Mechanical damage
ii) Delay in transport

Storage

i) Poor storage
ii) Insect infestation

Market level

i) Insect infestation
ii) Packaging
iii) Mode of transport
iv) Handling

A look at the loss estimates reveal that the fish loss in the mechanised fishing sector is more compared to the other sectors. Multi-day fishing leads to larger volume of discards at sea which has inflated the estimates. Use of stipulated mesh sizes to avoid juvenile fishing, use of by-catch reduction devices, utilisation of low value fishes for innovative product development and waste utilisation for production of fish based feed and manure will help reduction in harvest and post-harvest losses in fisheries. Training and awareness programmes on the responsible fishing methods developed by CIFT among the merchandised fishermen will check discards at sea. Under NAIP value chain project at CIFT, Cochin a number of innovative technologies for value addition from low value fishes were developed and demonstrated as viable business models for adoption by coastal fisherwomen. Popularization of these technologies along the coastal belt will enhance the income and livelihood of the fisherfolk.

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37. Gender based developmental approaches in sustainable fisheries management

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Prelude

We cannot solve global challenges unless women participate fully in efforts to find solutions. ('women holds half the sky'). The population of females in the world is estimated to be 3,905 million, representing 49.58% of the world population. Hence, female participation in the production sector is a critical driver for economic development of societies worldwide. When a woman is economically benefitted, it reflects positively in every facet of her life, the health, education and living standard of her family and ultimately it adds to the national income. Still, globally, women get lesser opportunities for playing a role in the economic activities than men, less right to access basic needs of life, education, information which poses serious threats on their health and safety and results in poor contribution for the national well being.

In India's population, females constituted 48.4% of it (as per census 2021) and India's sex ratio has improved in 2021, having 1020 females to every 1000 males, clocking a female majority for the first time. Hence, inclusive development has to gain more momentum in India.

Women's scenario in Fisheries

Fisheries and Aquaculture sectors support the livelihoods of approximately 10-12 percent of the world's population Globally, women make up 15 percent of people engaged in the fisheries primary sector. Of the 200 million people employed full- or part-time in the primary & secondary sectors for fisheries and aquaculture, women make up around half of the workforce. Even though women play important roles and contribute significantly to the fisheries sector, their hands remain pitiably invisible. While drawing the series of events lead to the formation Asian Fisheries Society and ICLARM The World Fish Center, in the Women in Fisheries program and to the move towards Gender and Fisheries initiatives in a report, Williams, M.J.2002 has expressed her concern over some major gender issues in fisheries sector like poverty, division of household labor, health, access to education and other rights, organizational culture and raising awareness and sharing knowledge.

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Table.1. Women of fisheries sector, especially in developing countries face substantive issues:

- Limited access to & control over assets & resources
- Time & labor burdens of unpaid work(household)
- Discrimination in division of labor & wages
- Digital divide
- Poor access to health, education and other rights
- Lack opportunities to hold managerial /decision making posts
- Hurdles for starting /sustaining entrepreneurship
- Small business only(low investment& low profit)

→

- Fewer opportunities
- Smaller returns
- Poor productivity
  Loosing self-esteem
- Poor living conditions
- Lower contribution to the Nation

Endeavours for Women inclusive growth

Eventhough more than 140 countries pledge gender equality through their constitutions, wom en face disparity in many forms, through laws, policies, rights to access resource and social practices. While looking back, the Seneca Falls Convention was the first women's rights convention held in July 1848 in Seneca Falls, New York, for women rights. The meeting opened the women's suffrage movement, which again took more than 70 years to give women the right to vote. Women's issues got a prominence on social and political platforms by 1960s and entered the development agenda in the late 1960s and 1970s. This was mainly because different several international aid agencies recognized that the reason for failure of many of their developmental projects was lack on women participation in the design and implementation. (Williams, M.J.2002).

Women in development (WID)

The WID approach was introduced primarily by "American liberal feminists" in 1970s and focuses on egalitarianism, especially in terms of economic participation and access (Rathgeber, 1990, p.490). Here the prime and only focus is on economic development. It addressed the disparity of employment opportunities between men and women. The concept is evolved based on a recognition of the significance of women in development process. The WID approach helped to make sure, the participation of women into the workforce and increase their level of economic productivity and improve their lives.

Women and development (WAD)

WAD is a “neo-Marxist feminist approach”, which took shape in 1975 in Mexico, is simultaneously a theoretical and practical approach to development. Previous thinking held that development was a vehicle to advance women. But here, concept is development was only made possible by the involvement of women and women are pictured as who were already involved in the process of development. The movement was against women only development projects, and gave prime importance for proving the relationship and role of women in development rather than making efforts to integrate women into development process.

GAD: Gender and Development

Gender The word gender indicates the socially-constructed roles and responsibilities that is considered appropriate for men and women by the relevant societies. The GAD approach, which was developed in the 1980s, stepped away from both WID and WAD and was founded in socialist-feminist ideology (Rathgeber, 1990, p.493). It focus is on the root causes of gender inequality and is not concerned with women alone, instead with the social construction of gender by assigning specific roles and responsibilities to different gender.

These efforts and approaches had its reflections in the different specific production sectors where women were involved like Agriculture, Diary, Fisheries, etc. Among the earlier initiatives which emphasized women in the development context (WID), the space for women in fisheries (WIF) was a specific case. This was because initially the interim goal was to ensure role of women in development programs & assure their sufficient involvement from which they were denied active participation in the past (Ostergaard 1992).

As per the latest State of World Fisheries and Aquaculture Report (SOFIA 2018) published by FAO, 59.6 million people were engaged in the primary sector of capture fisheries and aquaculture in 2016. Out of this, 19.3 million were in aquaculture and 40.3 million in fisheries. The FAO estimates that women represent nearly 14% of all people directly engaged in the fisheries and aquaculture. Sex disaggregated data is not available from many countries. Still, in Asia records maximum women employment, representing 15% of the total employment in capture fisheries while men represent 78% (SOFIA 2018) and the rest is not reported.

While considering the efforts for positive inclusion of women fisheries sector, the first major event was Global Workshop on Aquaculture, conducted in 1987, which was followed by a Workshop on Women in Fisheries in the Asia-Pacific region in 1995 as a preface of the Fourth World Conference on Women.

Table 2. Chronology of events related to women in development.

Date Events

1975 -The United Nations World Conference on Women (Mexico City)

1975 -1985 United Nations Decade for Women

1980 -Second World Conference on Women (Copenhagen)

1985 -Third World Conference to Review and Appraise the Achievements of the United Nations Decade for Women (Nairobi)

1987- The FAO Global Workshop on Women in Aquaculture (Rome)

1995- Workshop on Women in Fisheries in the Asia-Pacific region (Philippines)

1995- Fourth World Conference on Women (Beijing)

2000- Beijing +5: Women 2000 - Gender, Equality, Development and Peace for the 21st Century - Special Session of the General Assembly (New York)

Source: (Williams, M.J.2002)

Development agencies identified that women's economic empowerment is a critical aspect of achieving gender equality. It ensures an improvement in a woman's self-esteem, decision-making power, capacity to control over her life and also access to resources, which altogether result in the personal, family and societal development.

Gender equity, Gender Equality and GAD Sustainable Fisheries

Gender equity, as defined by the International Labor Organization (ILO), refers to "fairness of treatment for women and men, according to their respective needs." Gender equality, on the other hand, is defined by the ILO as the "enjoyment of equal rights, opportunities and treatment by men and women and by boys and girls in all spheres of life".

Towards a sustainable fishery through gender sensitive development efforts

In small-scale fisheries and aquaculture, the resources, strength and constraints and benefits of involvement for women are different from that of men. Hence, in any development programmes or projects while being planned for implementation in fisheries sector, it should have a special focus on gender concerns to ensure that the implementation is done in a inclusive manner, assuring equitable benefits to both the genders. For that, the following measures may be taken essentially;

- Information base on gender disaggregated data, gender-based issues and concerns may be collected in a flawless manner
- An analysis of constraints and opportunities may be done at every major programme planning stage in a gender perspective
- Interventions needed to promote women to fully participate in fisheries and aquaculture
- Provide a working gender friendly environment for women in all spheres of fisheries, wherever women can contribute productively
- Strike a gender balance in division of job responsibilities
- Provide continuous motivational and awareness sessions, not only to women, but

assuring the whole societal reach

- Form and assure implementation of gender friendly policies, programs and legislation Assure institutional frameworks for research & development as well as for gender mainstreaming to sustain continuity in gender sensitive

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38. Labour Challenges in fishing and fish processing industries

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Introduction

FAO observes that fish was one of the most traded food items in the world and an estimated 35% of all fish produced in the world, about 60 million tonnes worth about USD 143 billion, entered international trade in 2016 (FAO, 2018). The average per capita annual fish consumption was to the tune of 24.9 kg in developed countries, 20.5 kg in other developing countries, 12.6 in LDCs and 7.7 kg in low-income food-deficit countries (Table 1). This shows the key role fish plays in nutritional security of the world.

Table 1: Total and per capita apparent fish consumption by region and economic grouping

Region/ economic Grouping	Total food fish consumption (million tonnes live weight equivalent)	Per capita food fish consumption (kg/year)
World	148.8	20.2
World (excluding China)	92.9	15.5
Africa	11.7	9.9
North America	7.7	21.6
Latin America and the Caribbean	6.2	9.8
Asia	105.6	24.0
Europe	16.6	22.5
Oceania	1.0	25.0
Developed countries	31.4	24.9
Least-developed countries	12.0	12.6
Other developing countries	105.4	20.5
Low-income food-deficit countries	20.8	7.7

Source: FAO, 2018

More than 50% of of trade in seafood is from the developing to the developed world and the net trade income was valued at US$ 37 billion in 2016 (UNCTAD, 2018). Trade is essential for meeting demand from consumers along with economic expectations of countries. The increase in trade has been driven by globalization and liberalization of trade barriers and facilitation of freer trade between countries. Seafood is a major foreign exchange earner for several developing countries, and provides employment and income to millions of people. Fish is traded in different forms from live to value-added and even or non-food uses; and is supported by a processing sector, which can be vary in scale from small to very large. The

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processing industry itself has undergone tremendous changes from traditional methods of processing to more advanced and sophisticated processing technologies, inclduing increasing machine based processing in developed countries. The harvest, procesing and codnsumption of fish can be in different countries. Almost 45% of fish is consumed in fresh, live or chilled form followed by forzen (31%), preserved (12%), cured – salted, smoked or dried (12%) forms (FAO, 2018). Also almost 56 % of consumption in developing countries is catered to mostly in frozen or prepared forms, which is the major market for processed seafood from the developing countries.

World fisheries and aquaculture production and utilization

	2012	**2013**	**2014**	**2015**	**2016**	**2026**
Production (million tons)						
Capture						
Inland	11.2	11.2	11.2	11.4	11.6	
Marine	78.4	79.4	79.9	81.2	79.3	
Total Capure	**89.5**	**90.6**	**91.2**	**92.7**	**90.9**	**91.7**
Aquaculture						
Inland	42.0	44.8	46.9	48.6	51.4	
Marine	24.4	25.4	26.8	27.5	28.7	
Total aquaculture	**66.5**	**70.3**	**73.8**	**76.6**	**79.5**	**102.1**
Total world fisheries and aquaculture	**157.8**	**162.9**	**167.2**	**169.2**	**170.3**	**193.9**
Utilization (in million tons)						
Human consumption	136.9	141.5	146.3	148.8	150.9	177.4
Non-food uses	20.9	21.4	20.9	20.3	19.4	16.3
Population (billions)	7.1	7.2	7.3	7.3	7.4	8.1
Per capita food fish supply (Kg)	**19.3**	**19.7**	**20.1**	**20.3**	**20.4**	**21.6**

Sourced from UNCTAD, 2018

Original Source: OECD-FAO (2017), FAO, (2018). Source of population figures: United Nations, 2015.

Labour in the Sector

Fisheries and aquaculture have important roles in providing employment to millions of people in the world. FAO estimates that about 10-12% of the world's population may be employed in these sectors and 60 million people are directly and about 200 million people otherwise employed along the fisheries value chain (FAO, 2016), in activities as diverse as land based work in harbours, in processing facilities; and in other services.

Fish processing is a major post harvest activity and will involve multiple activities:

- Gutting and cleaning (for domestic markets)
- Pre-processing (for further processing)
- Processing (in factories for export)
- Drying, salting curing, smoking (largely traditional, catering to domestic markets)

Seafood exports from India

With a production of 35,99,693 tonnes in 2016 from marine and 14,62,063 tonnes from inland capture and 57,00,000 tonnes fronm aquaculture, India is one of the largest producers of fish in the world (FAO, 2018). It is also one of the top exporters of saefood with 5546 million USD and a share of 3.9% during the same year, with an annual average grwoth rate of 12.1% during 2006-16.

This seafood export is supported by a strong processing sector that has established itself ovr the past few decades. There are 551 processing plants with an insatlled capacity of 27813.81 MT, of which 313 plants are EU approved plants (http://mpeda.gov.in). Besides, there is a total storage capcity of 366315 MT , which included cold storage, chilled storage, dry fish storage and other storage.

Employment in the organised fish processing sector at various levels depending on the activity profiles of the industry, includes, the shop floor workers where the actual processing work takes place; the middle level and top level management; the loading/unloading workers at the shop floor; the supervisors (at the shop floor); the quality control professionals etc. In unorganized and traditional processing there is more informality in employment. The total workforce in seafood processing is not readily available, but several region or country based assessments are available (https://www.tsic.org.au; http://www.fpsc-ctac.com http://www.iuf.org).

Labour related policies in fisheries

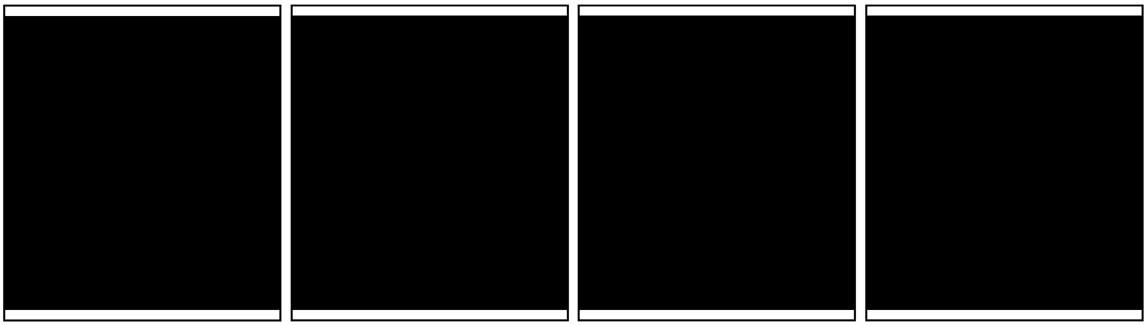
While there are no specific policies related to fish processing workers, several international and national policies cover the workforce in the industry. Some of the international covenants available are given below:

Access to decent forms and conditions of employment are enshrined in the Sustainable Development Goals. SDG8 is on 'Decent work and economic growth'. This was, among other things, necessitated because of widening inequalities, and not enough jobs to keep up with a growing labour force.' The targets specifically mentions 'decent job creation' and '…. achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value'

(http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-8-decent-work-and-economic-growth.html).
The ILO has set out the core labour standards (https://www.ilo.org) that are applicable in all employment situations. They are as follows:

- Freedom of association and the effective recognition of the right to collective bargaining (Convention No. 87 & No. 98)
- The elimination of all forms of forced and compulsory labour (Convention No. 29 & No. 105)
- The effective abolition of child labour (Convention No. 138 & No. 182)
- The elimination of discrimination in respect of employment and occupation (Convention No. 100 & No. 111)

With special reference to fisheries, concerned specifically with work on board fishing vessels is the Work in Fishing Convention, 2007 (No. 188). The Committee on Fisheries (COFI) of the FAO has also in its various Sessions decided on '…..legally mandated rights to decent working conditions…..' and '…..give priority to ensure decent working and living conditions in small scale fisheries………..' (http://www.fao.org/3/a-i5980e.pdf).
The four pillars of decent work are:



Source:http://www.fao.org/3/a-i5980e.pdf

While the international covenants give the broad framework for developing specific policies, countries have their own policies to regulate work in industries, including fish processing industries. The Ministry of Labour & Employment of the Government of India looks into policy making on labour and employment. An important national policy relates to ***Safety, Health and Environment at Work Place***. Policy making is guided by provisions under the Constitution as well in line with international instruments (https://labour.gov.in/policies/safety-health-and-environment-work-place). In the goals of the policy mention is made of 'providing a statutory framework on Occupational Safety and Health in respect of all sectors of industrial activities….' and in objectives '…..continuous reduction in the incidence of work related injuries, fatalities, diseases, disasters and loss of national assets'. Several acts support policy and some of them that are general in nature are applicable to the fish processing sector as well, like 'those related to compensation, wages, insurance and provident fund, maternity, contract labour (regulation), inter-state migrant workers, unorganized workers etc. which are enacted

under various sections like Industrial Relations, Industrial Safety & Health, Child & Women Labour, Social Security, Wages, Labour Welfare, Employment, Labour Reforms etc.
The EU has a Common Fisheries Policy (https://eige.europa.eu/..) that looks at employment in the sector, including Fisheries, Aquaculture and Processing. Individual states have their own bills and regulations for the sector. Several other international guidelines are also formulated like the Environmental, Health, and Safety Guidelines for Fish Processing by the World Bank Group (https://www.ifc.org/wps/wcm/......).

Challenges and Issues

Keeping the various international covenants in mind as well as the various state specific policies and programs, the issues and challenges in the sector can be assessed.

Fishermen on board

While the ILO has specifically looked at conditions on board, we still find that in most cases the problems still continue to persist. Fishing is considered one of the most hazardous jobs in the world. Traditionally fishermen went with no safety equipment ad depended on their knowledge of the seas to navigate and fish. Fishing has improved technologically with mechanization. However conditions onboard continue to remain the same. Lack of safety equipment, poor onboard basic facilities for crew engaged in fishing are common. There is risk of injury considering the type of jobs to be done during fishing, including risks of cuts and injuries due to falls. States are insisting on carrying proper safety equipment onboard due to increasing frequency of disasters. However, unless it is linked with the registration process this may be difficult to implement. It is additional expenditure and vessel owners have to either be incentivized or mandated to upgrade facilities. Migrant labour is increasingly a part of fisheries and they face exploitation of other kinds, including wage related inequalities.

Fish workers in harbours/ landing centres

Landing centres and harbours are places where there is constant use of water and ice. This is the major risk with possibility of slipping and falling common. Proper protective gear, which is also essential for proper handling of the fish, is important. Other facilities for the functionaries in landing centers and harbours, like proper sanitation facilities also are important.

Fish workers in marketing

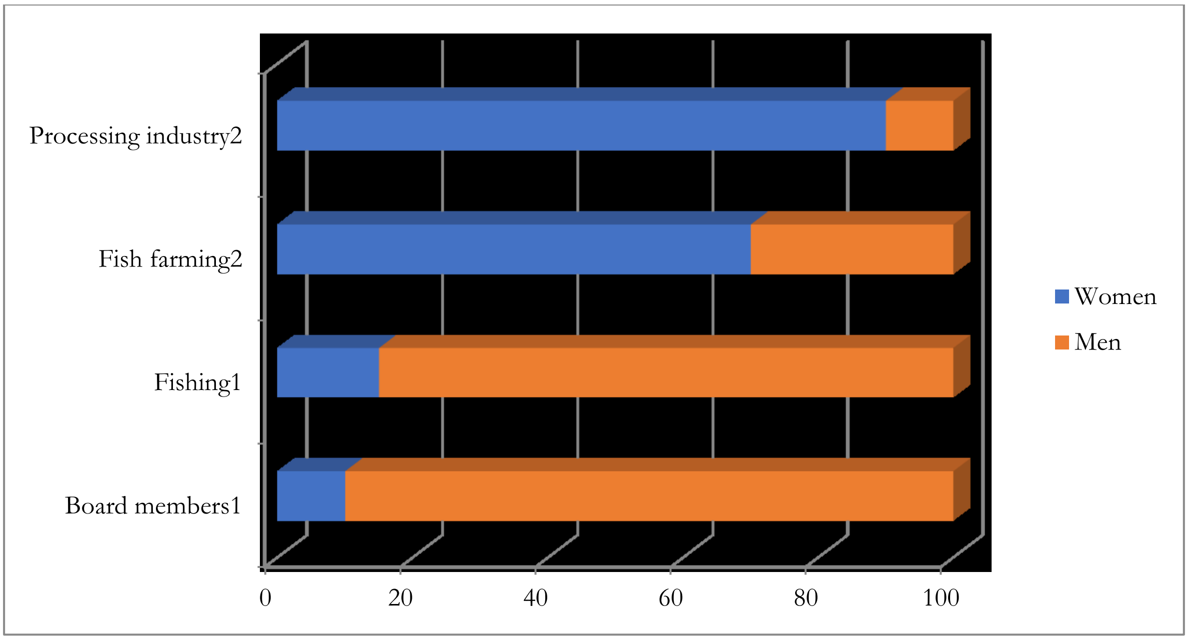
Marketing of fish is another important economic activity in fisheries value chain. Marketing can be done in harbours, in designated markets or door-to-door. Designated markets are generally poorly maintained and have all the issues that were discussed in the previous section. Wet, slippery floors, poor sanitation facilities, improper lighting and air circulation, cramped spaces are a few problems encountered by workers. Continuous squatting or standing also take a toll on health of these functionaries.

Work in the seafood processing

Work in the processing sector can be in organised processing plants or in the unorganized sector where traditional processing activities are carried out.

Traditional processing activities are curing –salting, smoking or drying. These activities are generally small scale and are community or homestead based. They are also mainly carried out by women. The major issues that arise in these activities are in relation to the repetitive nature as well as the conditions of work. Smoking results in release of gases that may be harmful to the persons involved. Sun drying exposes the women and men to harsh weather conditions and possibilities of sun burns. Excessive handling of salt and water also results in injuries to the palms.

Organized processing work involves primary processing like grading, peeling, cutting, gutting, washing of fish and shell fish or may involve other processing steps like brining, cooking, freezing, canning etc. Other jobs like handling, loading and unloading are also carried out. More than 80% of the workforce in seafood processing is women . (Monfort, 2015; World Bank 2010; Siason et. al. 2002; Jeebhay et al. 2004, Gopal et. al., 2009; Gopal et. al., 2007, De Silva, 2011; FAO, 2012; Ancy, 2016).. The processed product is then set into marketable forms or sizes before being frozen. Frozen products are once again packed by the women workers. The characteristics feature of this job is the need for dexterity and skill, but the work is repetitive and involves drudgery. The skill and dexterity that the women possess as well as the patience and ability to bear drudgery are the precise reasons for the domination of women in the sector. Montford (2015), in her summary of various studies observes that the women are preferred because they 'are perceived to be trustworthy, dedicated, meticulous, flexible, compliant, quality minded and cheaper than men.' However, sadly, they are still categorized as semi or unskilled in many countries.



1 WSI Article 2018 https://wsi-asso.org/media/

2 FAO. World Bank 0%

1The International Organisation for Women in the Seafood Industry (WSI)conducted a 'Gender on the Agenda' online survey from September to December 2017. Complete results are available at : https://wsi-asso.org/wsireports/

India

Most factories have a health check-up done before the start of the season. In all the processing plants surveyed, visiting doctor provision has been made usually on a monthly interval for check-ups. A few factories also reimburse the employees' medical bills. However, it is observed that they do not undergo any regular or periodic medical check-ups. The only source of information and entertainment is television and newspapers. However, all the workers possess mobile phones.

The work environment is generally cold as a very perishable commodity is being processed. This leads to exposure problems for most of the women involved in this job. Also slippery floors may cause slips and falls and injuries thereof. Constant standing or squatting leads to musculoskeletal disorders and repetitive strain injuries ((Gopal et. al., 2007; Jeyanthi et. al., 2015; Gopal et. al., 2016; Garcia and de Castro, 2017). Use of sharp tools may also lead to injuries. Constant exposure of the hands to ice, cold water and the raw material which could harbour pathogens also leads to infections of the palms.

Jobs can be repetitive and this can lead to fatigue and drudgery. Infrastructure may not always be adequate to meet personal hygiene requirements and women develop bladder related issues. Since work is related to availability of raw material and wages piece rate, there is practically no break time for the women workers. Work is generally done individually and spaces are confined with little interaction among workers. Shifts during the night may also lead to sleep disorders. There is also a risk of exposure to chemicals. The industry is increasingly catered to by migrant labour and this brings in its wake issues of cultural differences.

To minimize Occupational health and safety issues proper guidelines are available, implementation of which can reduce the risks associated (https://www.ifc.org/wps/wcm/......) like following sector-specific recommendations for accident prevention, including providing workers with training in the proper use and maintenance of cutting equipment and personal protective equipment. Plants should be so designed that process flows smoothly. Several guidelines like provision of hand rails, separate transport corridors, enclosed conveyer belts, etc. will ensure safe work environments. Use of gloves to prevent cold bites and infections from pathogens is also recommended. Proper ventilation, protective clothing, lighting, temperature control, workspace design to minimize ergonomic distress can be ensured.

Conclusion

The issues associated with labour working in the different nodes of the fisheries value chain have been existent since the time fishing has been an avocation. While there are are several international and national laws addressing labour issues, the on the sector level policy formulation and program implementation need to be strengthened to ensure safe and decent work and working conditions for fishers and fish workers.

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39. Technology Application, Refinement and Transfer through Krishi Vigyan Kendras

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Introduction

India has made considerable progress in improving its food security. The agricultural development strategy pursued in the country, particularly since the mid-sixties, is recognized and appreciated world over. The integration of agricultural research with quality education and a properly planned extension education system has been one of the fundamental foundations of this developmental strategy, which also led to revolutions in many other sectors of agriculture and allied enterprises. As a part of this strategy, several programmes of transfer of technology from research stations to farmers' fields were launched in the country. These included National Demonstration Project, Lab to Land Programme, Operational Research Project and Krishi Vigyan Kendras (Farm Science Centers). The programmes were continuously reviewed from time to time and reformulated for their effectiveness. Presently the Krishi Vigyan Kendras (KVKs) have been recognized as an effective link between agricultural research and extension system in the country (Venkatasubramanian *et. al.*, 2009).

Krishi Vigyan Kendras (Farm Science Centers), an innovative science-based institution, were established in India mainly to impart vocational skill training to the farmers and field-level extension workers. The concept of vocational training in agriculture through KVK grew substantially due to greater demand for improved/agricultural technology by the farmers. The farmers require not only knowledge and understanding of the intricacy of technologies, but also progressively more and more skills in various complex agricultural operations for adoption on their farms. The effectiveness of the KVK was further enhanced by adding the activities related to on-farm testing and front-line demonstrations on major agricultural technologies.

With the consolidation of other front-line extension projects of the Council during the Eighth Five Year Plan, such as National Demonstration Project (NDP), Operational Research Project (ORP), Lab to Land Programme (LLP) and All India Coordinated Project on Scheduled Caste/Tribe, the mandate was enlarged and revised to take up on-farm testing, long term vocational training, in service training for grass root extension workers and front-line demonstrations on major cereal, oilseed and pulse crops and other enterprises.

The application of technology in the farmers' field is achieved through conducting of On-farm trial which include technology assessment and refinement. The proven and recommended technologies are then introduced in the system through conducting of frontline demonstrations followed by training programmes to empower the farmers, field extension personnel and rural youths for its adoption. The extension activities such as field day, exhibitions etc are conducted to disseminate the technologies across the system.

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The KVKs have witnessed several changes in their functions over the years. Accordingly, their functional definition also has radically got refined so as to meet the new challenges in agriculture. “KVKs are grass root level organizations meant for application of technology through assessment, refinement and demonstration of proven technologies under different ‘micro farming’ situations in a district” (Das, 2007). As of October, 2021, 722 Krishi Vigyan Kendras were operating in 748 districts of India (ICAR, 2021).

It should be clearly understood that transfer of technology is not a primary function of KVKs and the same is the responsibility of State departments. The KVKs on the other hand will assess (and if needed refine also) the newly released technologies, demonstrate the proven ones and train farmers and extension workers of the district on the same. Presently, the vision, mission, mandate and activities of KVKs are as follows:

Vision
Science and technology-led growth leading to enhanced productivity, profitability and sustainability of agriculture
Mission
Farmer-centric growth in agriculture and allied sectors through application of appropriate technologies in specific agro-ecosystem perspective
Mandate
Technology Assessment and Demonstration for its Application and Capacity Development
Activities

- On-farm testing to assess the location specificity of agricultural technologies under various farming systems.
- Organize Frontline Demonstrations to establish production potential of technologies on the farmers’ fields.
- Capacity development of farmers and extension personnel to update their knowledge and skills on modern agricultural technologies.
- To work as knowledge and resource centre of agricultural technologies for supporting initiatives of public, private and voluntary sector in improving the agricultural economy of the district.
- Provide farm advisories using ICT and other media means on varied subjects of interest of farmers

Role of KVKs in the context of Agricultural Extension in India

Extension in India is largely deployed by government, implemented mainly through government institutions and to some extent through non-government agencies. Krishi Vigyan Kendras (KVKs) or Farm Science Centres as institutes of inducing behavioural change, are being managed by both government and non-government organizations. Literally, Krishi Vigyan Kendras have to serve as repository of scientific knowledge that is useful to the entire district, which is its jurisdiction. In India, agricultural/fisheries extension and extension education are interchangeably used with the same connotation as used in American tradition, meaning “Extending Information” as a means of educating people to solve their problems. As a result, agricultural/fisheries extension in India is more of “Informative Extension” than “Emancipatory Extension”.

In India, the extension efforts, particularly transfer of technology efforts, have largely been taken up by the state departments of agriculture and other disciplines as a state subject. The Indian Council of Agricultural Research (ICAR) as the apex body to provide new technologies in agriculture and allied aspects has its own transfer of technology activities too. The extension efforts of ICAR have evolved through National Demonstration Projects, Operation Research Projects, Lab to Land Programmes, and integrating of these approaches to Krishi Vigyan Kendras (KVKs) since 1974.

Technology and farm technology

Technology is any systematic knowledge and action applicable to any recurrent activity. Technology involves application of science and knowledge to practical use, which enable man to live more comfortably. The Merriam-Webster dictionary offers a definition of the term: "the practical application of knowledge especially in a particular area" and "a capability given by the practical application of knowledge”.

Technology can be most broadly defined as the entities, both material and immaterial, created by the application of mental and physical effort in order to achieve some value. In agriculture/fisheries, the term technology often confuses practitioners. This is because farm technology is a complex blend of materials, processes and knowledge. Swanson (1997) has classified farm technologies into two major categories: 1) Material technology, where knowledge is embodied into a technological product; and 2) Knowledge based technology, such as the technical knowledge, management skills and other processes that farmers need for better farm management and livelihood support.

KVK scientists need to have clarity over the technologies which they are assessing and refining in response to a specific problem in a specific micro-location. For example, a KVK Subject Matter Specialist may be assessing the efficacy of a particular management practice on a crop/fish’s yield or growth in the KVK district. Such management practices can be broadly classified as Knowledge based technology. Alternatively, all technological products tested and demonstrated under OFT and FLD fall under material technology. Ex: Seeds/fish seeds, pesticides, fertilizer, farm machinery, irrigation systems etc.

Agricultural Technology Development

Technology Development (also called technology innovation) in agriculture/fishery is a process consisting of all the decision and activities which a scientist does from recognition of a need/ problem with planning, testing, conducting research, verification, testing and dissemination for adoption. During the same time, some problems on the technology might get back to the scientist for solution thus resulting in refinement of the same. Thus, technology development is a continuous process. The KVK scientists have to equip themselves for ‘technology application’ - a process which includes the above mentioned processes; thus contributing their part in the overall process of agricultural/fishery technology development.

Agricultural Technology Management

Technology management can be defined as the integrated planning, design, optimization, operation and control of technological products, processes and services. A better definition would be "the management of the use of any technology for farmer advantage." The KVK role under fishery technology management is very huge where-in it selects latest fisheries technologies, tests them for suitability in different micro-locations of the district and demonstrates the proven ones to farmers and extension system.

Technology fatigue in agriculture

Linkages between the laboratory and farmer fields have weakened and extension services often have little to extend by way of specific information and advice on the basis of location, time and farming system. Good quality seeds at affordable prices are in short supply and spurious pesticides and bio-fertilizers are being sold in the absence of effective quality control systems. Farmers have no way of getting proactive advice on land use, based on meteorological and marketing factors. No wonder the prevailing gap between potential and actual yields, even with technologies currently available, is very wide (National Commission on Farmers, 2007). In case of KVKs, it was found utilizing old and obsolete technologies for OFTs, FLDs and training programmes thus resulting in poor feed-forward to the extension system. A knowledge deficit as mentioned above coupled with the usage of obsolete technologies and package of practices together leads to a situation called 'technology fatigue'. Indian agriculture, particularly agriculture/fishery by resource poor farmers in rural areas is now bearing the brunt of technology fatigue. The KVK role lies in providing timely supply of proven technologies specific to various micro-locations of the district thus alleviating the technology fatigue existing in the district.

Technology Gap

Technology Gap is the gap between the level of recommendation and the extent of adoption (against recommendations). Technology gaps are a major source of concern for extension system. The successes of traditional transfer of technology (TOT) models were mainly evaluated on the basis of the extent of narrowing down in technology gaps achieved by them. KVK system being primarily focused on assessment, refinement and demonstration of new technologies, its role lies in feeding proven technologies to the main extension system. Thus, the primary focus of KVK should not be mistaken as reduction of existing technology gaps. Rather, they are meant at alleviating "technology fatigue" by providing timely supply of proven technologies specific to various micro-locations of the district. Alleviation of technology fatigue is accomplished through processes of technology and methodology backstopping.

Agricultural Technology backstopping

Backstopping refers to any precaution taken against an emergency condition. Accordingly, agricultural technology backstopping can be defined as any technology precaution taken to combat technology fatigue in agriculture. In simple terms agricultural technology backstopping is the process of making available ready to use technologies for farm families through assessment, refinement and demonstration processes in order to combat the existing/forecasted technology fatigue.

Agricultural Methodology backstopping

This is a process almost similar to agricultural technology backstopping but differs with respect to the kind of technology solution offered. Instead of material technology, methodology backstopping aims at assessment, refinement and demonstration of knowledge based technologies often referred to as methodologies/package of practices. It provides detailed procedures to carry out the technology application functions by the extension personnel in the field. It includes methodologies for conducting OFT, which includes TAR, demonstrations, training, conducting surveys, impact assessment and evaluation etc.

Conceptual paradigm of Agricultural/Fishery Technology Development

Understanding technology development process in agriculture/fishery and its components is vital for success of KVK scientists. Farm technology development basically constitutes seven processes. They are:

1. Technology generation
2. Technology testing

Technology Assessment and Refinement (OFT)

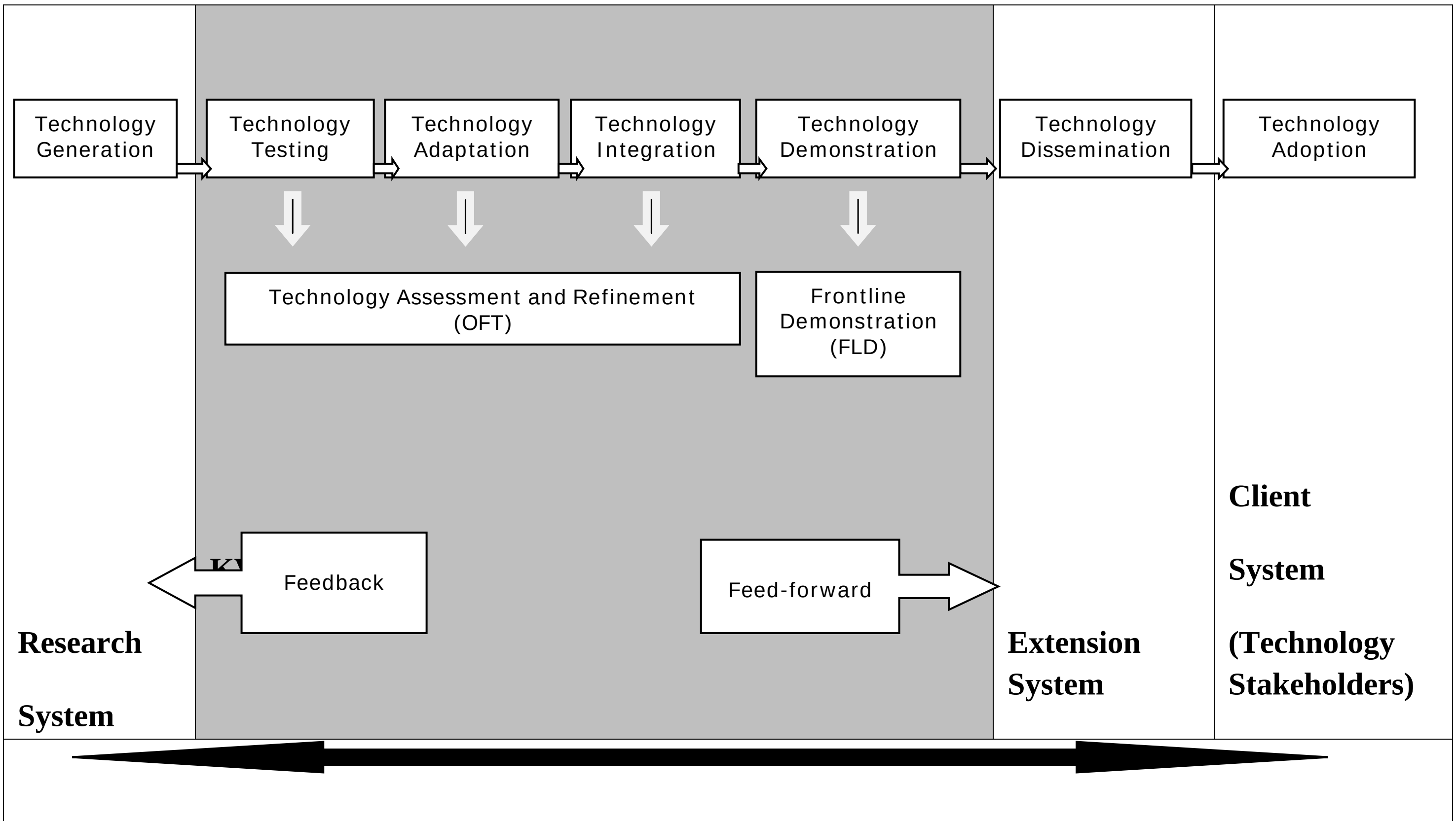
3. Technology adaptation
4. Technology integration
5. Technology demonstration

Frontline Demonstration (FLD)

6. Technology dissemination
7. Technology adoption

Technology generation, the starting point of technology development process is mainly a function of agricultural research system. Testing, adaptation and integration processes constitute technology assessment and refinement which KVK system executes through OFTs. The feedback is passed over to research system. KVK system also involves in technology demonstration through FLDs. Feed-forward from successful OFTs and FLDs is communicated to the extension system for mass popularization in the district. Technology adoption; the final act, occurs among the members of client system i.e. farmers.

We are presenting a new conceptual model of fishery technology development process depicting the various components and actors involved for the benefit of fisheries technology stakeholders. The role of KVK system between research system and extension system with respect to technology application is identified and highlighted here. Research system generates new technologies. In India, research system comprises of ICAR institutes, SAUs, Fishery Universities, departments like DBT, DST, other Science and Technology Institutions and Commodity boards. NGOs, Corporate and farmer innovators also contribute to technology generation. Extension system comprises of State departments of agriculture, animal husbandry and veterinary, fisheries, sericulture etc. SAUs, ICAR institutes, commodity boards, NGOs and Corporate sector also contribute to extension system. Earlier, due to the primary focus on vocational training, KVKs were categorized under extension system itself. But today, with mandates being focused on assessment, refinement and demonstration of frontier technologies, the KVK system positions itself clearly between the research and extension systems thus acting both as a feedback and feed-forward mechanism. In this paradigm, it is necessary to understand the pathways or passage of technology through KVK system.



A Conceptual model for Technology Development Process *(Sajeev, 2021)*

Typology of technology passage through KVK system

KVK system has successfully established itself between the research and extension systems. Technology development process as explained earlier, invariably has assessment, refinement and demonstration components. Hence, there is a passage of technologies through various stages in a KVK system. We found that this passage doesn't follow a uniform pattern. For example, a technology may go through assessment stage and demonstration stage but not through refinement stage. Based on analysis of OFTs and FLDs conducted by KVKs, we identified five different typologies of technology passage through KVK system. A proper understanding of these typologies will help KVK personnel in deciding whether a particular technology has to go for OFT and FLDs or both. The typologies are:

1. **Source - Demonstration**

In this type the technology from any source/provider directly goes to demonstration by KVK. This happens when the KVK is completely sure that the technology is fully suited for the district and can go directly for FLD. Here, the technology doesn't pass through assessment and refinement stages.

2. **Source - Assessment**

In this type the technology from any source/provider goes for assessment by KVK. This happens when the KVK is not sure that the technology is fully suited for different micro-locations of the district. Here the technology fails at assessment stage itself and hence doesn't move to refinement or demonstration stages.

3. **Source - Assessment - Refinement**

This type is a variation of type 2. Here, the KVK is not sure that the technology is fully suited for different micro-locations of the district. The technology goes for and succeeds in assessment but needs refinement and hence moves to refinement stage. Here, the technology fails in refinement stage and hence doesn't move to demonstration stage.

4. **Source - Assessment - Demonstration**

This type follows type 3. This happens when the KVK becomes sure that the technology is fully suited for different micro-locations of the district. The technology fully succeeds in assessment and hence moves to demonstration stage. Here, the technology doesn't require refinement and hence move to demonstration stage.

5. **Source - Assessment - Refinement - Demonstration**

This type also follows type 3. This happens when the KVK becomes sure that the technology is fully suited for different micro-locations of the district. The technology succeeds in assessment and refinement and moves to demonstration stage. Here, the technology is successfully refined by KVK and taken to demonstration stage i.e. FLD.

FLDs are supposed to be taken up on proven technologies only. Hence, it makes obvious that once demonstrated it will go to the extension system and client system. Rarely FLDs may fail thus preventing the technology passage. But KVKs are not supposed to demonstrate such technologies which are not fully proven. The failure of FLD can be due to some extraneous factors rather than technological factors.

Client system comprises of the ultimate end-user i.e. the fish farmer/fishery technology stakeholder. Although KVK system does assessment, refinement and demonstration of new technologies as part of technology development process, some technologies get refined or rejected even in the last stage at farm/user level. Hence, client system even though being the final actor in technology development process, plays the ultimate decisive role.

Conceptual paradigm for Technology Assessment and Refinement in agriculture/fisheries

Technology Assessment and Refinement (TAR) in agriculture refers to a set of procedures whose purpose is to develop recommendations for a particular agro-climatic situation/ location through assessment and refinement of recently released technology through farmer participatory approach. It refers to the process or a set of activities before taking up new scientific information for its dissemination in a new production system. *OFTs conducted by KVKs are based on this concept and thus distinguish it from agronomic and research trials*. The process of TAR has three components. They are technology testing, technology adaptation and technology integration. TAR should be site specific, holistic, farmer participatory, providing technical solution to existing problems, inter-disciplinary and Interactive.

This process involves Scientist-Farmer linkage in terms of sufficient understanding of the farming situations, adequate perception of farmers' circumstances and their needs, the variability of conditions on the research status as compared to farmers' fields and problem orientation instead of disciplinary approach.

Thus, Technology assessment in agriculture by KVKs should be understood as the study and evaluation of new technologies under different micro locations. It is based on the conviction that new discoveries by the researchers are relevant for the farming systems at large, and that technological progress can never be free of implications. Also, technology assessment recognizes the fact that scientists at research stations normally are not trained field level workers themselves and accordingly ought to be very careful while passing positive judgments on the field level implications of their own, or their organization's new findings or technologies. Considering the above factors, the ICAR has envisaged On Farm Trials (OFTs) through its vast network of KVKs covering almost the entire geographical area of the country (Anon, 1999).

On Farm Trials (OFTs)

An On-Farm Trial aims at testing a new technology or an idea in farmer's fields, under farmers' conditions and management, by using farmer's own practice as control. It should help to develop innovations consistent with farmer's circumstances, compatible with the actual farming system and corresponding to farmer's goals and preferences. On-farm-trial is not identical to a demonstration plot, which aims at showing farmers a technology of which researchers and extension agents are sure that it works in the area. *It should be noted that OFTs are strictly to be conducted in collaborating farmer fields and not in KVK land.*

Stakeholders of On-farm trials

There are various stakeholders in an on-farm trial. Understanding them and their roles can help KVKs to develop better OFTs. The stakeholders are:

1. The farmers who are the clients for the out-coming results,
2. The SMS who should help the farmers to overcome their problems and improve their economical situation. On farm trials can give them valuable information in this respect.
3. The Scientist who needs to apply promising on-station results under farmers' conditions before releasing the technology to the extension service,
4. The extension system and government itself, who is interested in seeing an efficient and participatory technology development model evolving, since most top-down approaches have failed miserably.

KVKs have to spend considerable time and efforts in planning and implementing OFTs. The basic principles of conducting successful OFTs are to be followed in this process. The principles are:

1. *Define a clear question you would like to have an answer for:*

Narrow the trial down to its simplest form; define a clear simple question to which the OFT should give an answer.

2. *Keep it simple:*

Limit the trial to a comparison of two (or maximum three) treatments.

3. *Go step by step:*

Farmers usually do not adopt entire new systems of production; they go step-by-step adapting components of the technology. Therefore the OFT should not include too many new steps/practices at once.

4. *Seek help:*

When the problem is clear and the idea on how to go about the trial has evolved, the SMS should contact a competent researcher to discuss the plan of the OFT. He/She can also take help from other SMS and PC of the KVK.

5. *Replicate and randomize*

Plan on enough field space (in farmers' field) to do more than one strip of each treatment being tested. Mix treatments within blocks.

6. *Stay uniform:*

Treat all the plots exactly the same except for the differing treatments. If possible, locate the experiment in a field of uniform soil type (slope, fertility etc.).

7. *Harvest individual plots:*

Record data from each individual plot separately. Do not lump all treatment types together or the value of replication will be lost.

8. *Remain objective:*

The results may not turn out as expected or planned. Be prepared to accept and learn from negative results. Negative results show that the technology under testing is not suitable in the present form for the specific micro-location of the district. Such results are equally valuable for the benefit of farming systems at large.

9. *Manage time wisely:*

Expect to devote extra time to OFT during busy seasons. Make sure to can carry out the trial even though busy, or get extra help from other SMS.

The success of an OFT should not be confused with success of the technology tested. A negative result of a technology tested shows that the technology is not suited for the specific micro-location of the district. This finding also refers to the success of the trial. Some technologies may not need refinement thus qualifying directly for frontline demonstrations. Some may successfully undergo refinement and reach the demonstration stage while some technologies fail to get refined in the farmer field. The technologies which successfully come out of On Farm Trials are then recommended for Frontline Demonstrations (FLDs).

A study conducted by National Institute of Labour Economics Research and Development during 2015 on impact of KVKs on dissemination of improved practices and technologies revealed that KVKs are having an edge over other organizations in providing technology services by virtue of their having better technical expertise and demonstration units. At national level, on an average each KVK covers 43 villages and 4,300 farmers, and it organize more field level activities than on campus activities. About 25% of the persons trained by KVKs on agri-preneurship had started self-employment venture.

Krishi Vigyan Kendra Knowledge Network Portal

Krishi Vigyan Kendra Knowledge Network Portal facilitates KVKs to update and upload all types of information so that the related information and knowledge can reach to the farming community in time. A KVK Mobile App for farmers has also been developed for Android users and is available in Google Play Store. Farmers need to register and select concerned KVK in the App for accessing information. Farmers can ask any farm related query to the experts of KVKs for solution.

Conclusion

With current reforms and policies, the public extension system would continue to play a prominent role in technology dissemination. The large scale of small and marginal farmers and landless labourers are benefited by the public extension system. The other players involved in extension/transfer of technologies such as NGOs, Farmers organisations, Private sector (both corporate and informal), para-workers etc. would actively complement/ supplement the effort of the public extension agency. Extension mechanism will have to be driven by farmer's needs, location specific and address diversified demands. There is room for both the public and private sectors in the development of a demand based and feedback driven system. Technologies required to address total farming systems are knowledge intensive. Public extension system will need to be redefined with focus on knowledge-based technologies to upgrade and improve the skills of the farmers.

Farmers' capacity building is often seen within the limited perspective of giving them the knowledge and skills required to practice crop and animal husbandry in a better way. Though, knowledge and skills are fundamental to efficiency in any enterprise, the Indian farmers need more than that because of the limitations and complexities under which they operate. The KVKs which have been mandated to work with farmers, farm workers and rural youth directly as well as through field extension functionaries have the greatest challenge to make their clients more efficient, specialized and to be economically active. The fact that the need for agricultural/fisheries and rural information and advisory services is to intensify in the immediate future exerts more pressure on KVK performance. This article has attempted to assist the extension practitioners in equipping themselves for the future challenges by providing a conceptual paradigm regarding technology assessment and refinement, the most important mandated activity assigned to them.

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40. Global fisheries value chain: Issues and Opportunities

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1. 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.

2. 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

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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.

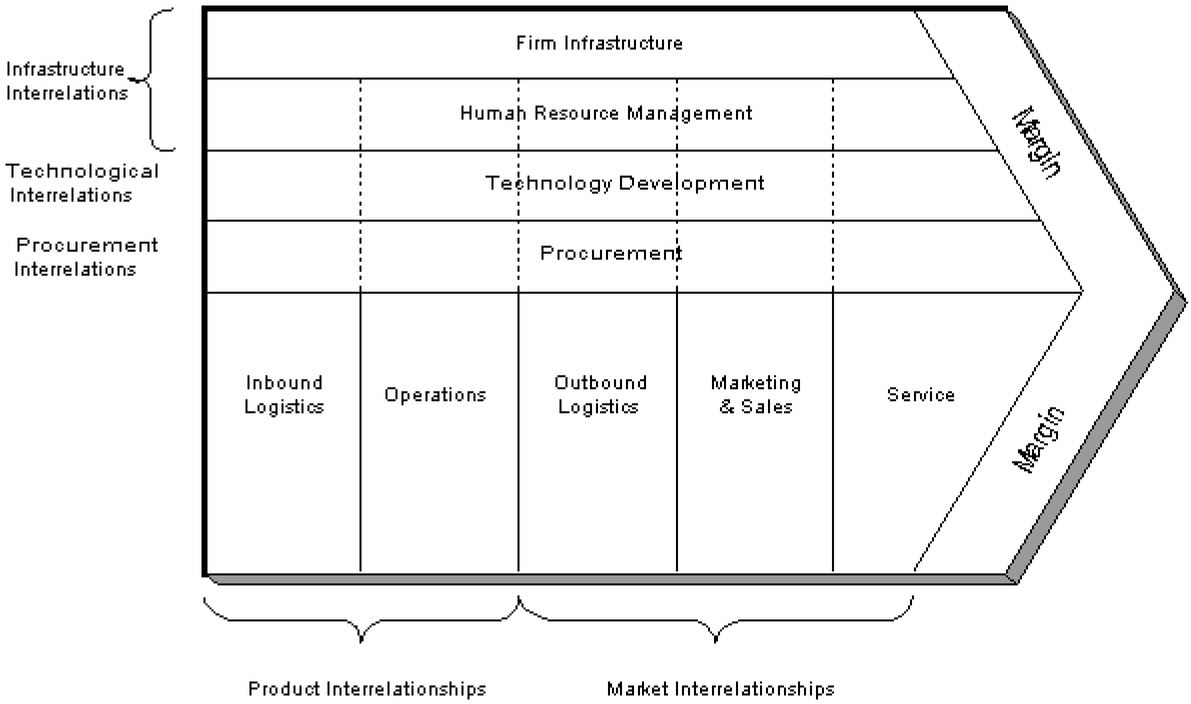


Figure 1: Michael Porter's value chain concept

3. 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.

4. 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.

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)

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. 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 developemtn

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

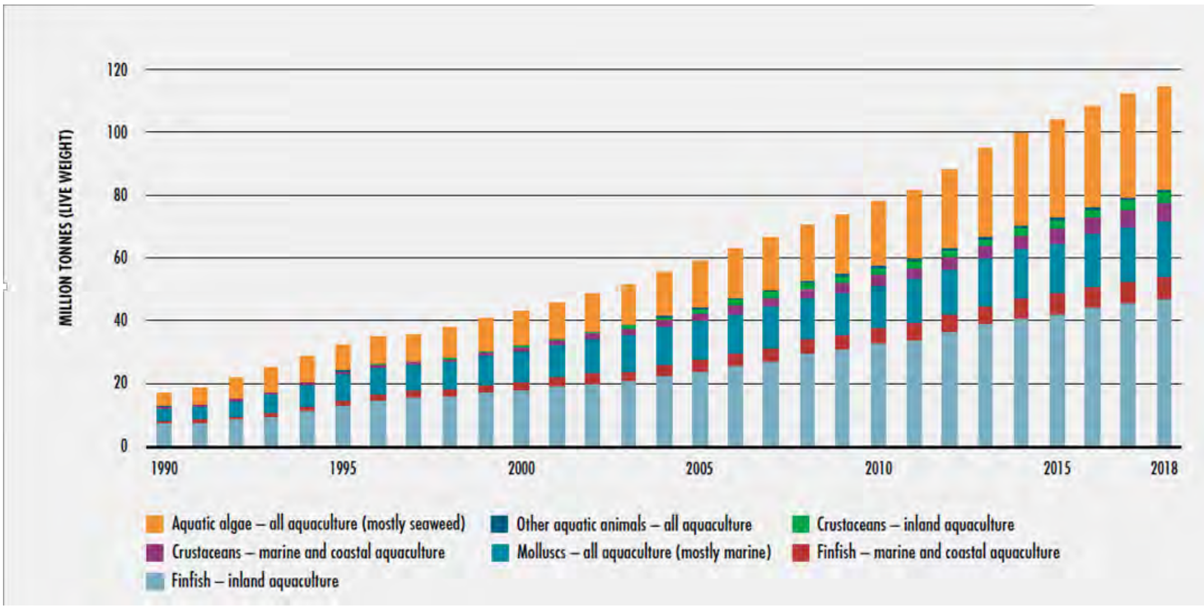
A Value Chain analysis assesses whether the value chain is effective at maximising the opportunities for adding value in the eyes of the consumer; and efficient in adding value, producing, processing and distributing at the least cost (CRFM, 2014). Value is getting added at every step or node in the 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.

5. 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).

6. 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 allow 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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