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Advanced Techniques in Fishing and Fish Processing

31 August - 9 September 2021

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www.cift.res.in E-mail: cift@ciftmail.org, directorcift@gmail.com

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on

Advanced Techniques in Fishing & Fish Processing

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Director, ICAR-CIFT

Ravishankar C.N.

AARDO Programme Coordinator

A.K. Mohanty

Programme Facilitator

Sanjeeb Ku. Behera

Kamal Dhameja

Course Coordinators

Leela Edwin, K. Ashok Kumar, Saly N. Thomas, George Ninan, M.P. Remesan, Muhamed Ashraf

Course Co-Coordinators

V.R.Madhu, M.V. Baiju, V.Chandrasekar, A.Jeyakumari, Remya S, Parvathy U & Paras Nath Jha

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V. Chandrasekar, Scientist, ICAR-CIFT, Cochin.

FOREWORD

With the rise of the nutritional consciousness among the consumers, fish is fast growing as much sought-after food. As we progress towards the middle of the century, it is desirable to take note of the emerging trends in the sector and make appropriate changes in the strategic plan and programmes, in response to the changing scenario. Technology is perceived as the key input to bring transformation amidst the rapidly changing scenario impacted by environmental issues, climate change and associated stresses and increasing resource needs. The ICAR-Central Institute of Fisheries Technology, Cochin, over the past more than six decades, has been maintaining a rich legacy of devoting itself to research in the domain of harvest and post-harvest fisheries and has proved its existence through commendable contributions in the sector. The Institute has been instrumental in modernising both the fishing and fish processing sectors in the country and continues to support both these industries through need-based research and technology interventions., which has resulted in better harvesting and utilization of fishery resources.

In fact, collaboration in research and training among various organisations may yield rich dividends, particularly in terms of human resource development and technology transformation. I am really happy to note that African Asian Rural Development Organization (AARDO) has come forward to foster collaboration with ICAR-CIFT for the capacity building of human resources in Asian and African countries with advanced technologies in fishing and fish processing, which may promote co-operation and exchange of knowledge in the field of harvest and post-harvest fisheries aligned with the objectives of AARDO.

I am very much happy that this international training programme on *'Advanced techniques in fishing and fish processing'* (31 Aug.- 09 September, 2021) organized by ICAR-Central Institute of Fisheries Technology, Cochin, India under the sponsorship of African-Asian Rural Development Organization (AARDO), New Delhi assumes greater significance as the technical expertise developed over many decades by the institute could be shared with researchers and officials from other countries. Over a period of eight days, 103 participants from 22 different countries from Asia and Africa working in various establishments were exposed to trailblazing technologies of ICAR-CIFT in fishing and fish processing. The course programme was designed meticulously to give a comprehensive knowledge on various aspects of modern fishing techniques and traditional as well as innovative fish processing methods.

I sincerely appreciate the efforts of Course Coordinators, Course Co-coordinators of this AARDO training programme in bringing out a comprehensive e-training manual covering different facets of fishing and fish processing like improved fishing gears, active and passive fishing methods, fishing vessel design, fish processing methods, fishery waste utilization and value addition of seafood. I am sure that this compendium will be very useful for the academicians, researchers, policymakers and entrepreneurs working in the areas of fishing and fish processing as a reference manual.

Dr. Ravishankar C. N.
Director

Content

Advancements in Active Fishing Methods

Madhu V.R.
Principal Scientist,
Fishing Technology Division, ICAR- CIFT, Cochin
Madhu.VR@icar.gov.in

1. Introduction

Fish harvesting technology has advanced dramatically over the last many decades. Among the most significant developments in the history of fishing gear and practices are the following:

(i) Technological advancements in craft design and mechanization of propulsion, gearing, (ii) adoption of synthetic gear materials (iii) changes in techniques for detecting fish using acoustics and satellite-based remote sensing (iv) technological advancements in electronic navigation and communication systems (v) awareness of the importance of responsible fishing in ensuring the long-term viability of resources, biodiversity protection, environmental safety, and energy efficiency.

Introduction of highly effective and powerful fish harvesting systems and fish detection techniques, as well as an unchecked expansion of fleet size, fueled by increased market demand for fish resulted in increased pressure on global fisheries resources. Signs unmistakable of overfishing and Negative effects on ecosystems have become more visible in recent years, emphasizing the importance of scientific fisheries management to ensure their long-term viability and future generations' accessibility.

Fishing vessels

Significant advancements in fishing vessel materials, hull optimization, engine performance, propulsion systems, gear and catch handling deck equipment, onboard preprocessing, processing, preservation, and packaging systems, and energy conservation have occurred. The navigation controls and displays are increasingly integrated into a single large display. Improvements in the devices like navigational instruments that are used to navigate the vessel at sea and in port, other instruments that are used to detect fish and aid in the fishing operation, such as sonar and electronic aids for the operation, and radio communications that are critical for safety and general communication.

Fishing gear materials

Significant advancements in fiber technology have occurred in recent decades, and so has the introduction of other modern materials. With the introduction of man-made synthetic fibers, natural fibers used in fishing gear were gradually phased out in favour of these synthetic materials due to their high breaking strength, resistance to weathering, low maintenance cost, long service life, and improved characteristic uniformity.

Polyamide (PA), polyester (PES), polyethylene (PE), and polypropylene (PP) are the most used synthetic fibers in fisheries. Other synthetic fibers include polyvinyl alcohol (PVAA), polyvinyl chloride (PVC), and polyvinylidene chloride (PVD), which are less widely used. The introduction of synthetic materials with high tensile strength properties like Ultra High Molecular Weight Polyethylene (UHMWPE) enabled the design and size of fishing nets to be reconfigured considering the available engine power of the vessels from which they are operated.

Fishing gears

There are a wide array of fishing gears that are being used, that typically suits the ecology and behaviour tendencies of the fishes that are being targeted and the fishing gears are classified based on the principle of capture, design and technical features and the operational methods.

Historically, technological advancements in fishing gear and methods were targeted at improving production through improved gear system efficiency.

However, in the current environment of overfishing and increased awareness of fishing's environmental and ecological impacts, fishing gear development efforts are concentrated on the development of responsible fishing gear systems with improved size- and species-selective properties, reduced impact on the environment and non-target resources, and increased fish stock sustainability.

2. What are active fishing methods?

Active fishing methods are fishing operations which involve some mechanical energy to be expended to capture fish, it differs from the passive methods of fishing, which predominantly lures the fish to a particular location/ area by different methods and then finally lifted out with very low energy requirement.

Depending on the type of operations and the amount of energy that is expended for the capture, wide variation exists in active fishing methods. For instance, the energy requirement of in case of hand dredge and double stick nets, are very low when compared to large mid water trawls, which spends large amounts of fuel for towing large net at speeds that outrun the speed of large pelagic fishes, that it intends to capture.

Most of the active fishing methods, particularly the dredges and trawls, are often implicated for collateral damages to biota and to affect the integrity of the ecosystems. Hence most of the recent advancements in the field of active fishing methods, has been to reduce the negative impacts and to improve the efficiency of the mechanical systems to conserve or optimize the energy use.

3. The classification of the most important active fishing methods

3.1. Dredges

The area of operation of this gear is along the inshore and offshore sea waters all along the world. Smaller boats are often employed for the inshore operations, with use a single dredge, whereas in offshore fisheries, particularly that target scallops along North America and Alaska, large vessels are often used, that employ two or three dredges.

Mechanization and large number of sophisticated methods are now employed, in dredges, particularly the offshore fisheries, which can dig and transport the catch to the vessel using mechanical conveyers, which can be considered as harvesting machines.

Direct and in-direct impacts of dredging operations

The impacts of dredging include, 1) damage to reef structures, 2) by-mortality, 3) sediment suspension and chemical changes, 4) reduce chemical exchange between water-soil interface etc. Though the physical changes diminish with time, but changes to ecosystems that are vulnerable, often take many years to revive. The effects are often a function of the type of dredge used, number of dredges operated by a vessel, use of rakes or deflectors etc.

Dredge selectivity is affected by several factors including the type of seabed, depth, tow duration and speed, the hanging coefficient of the net bag, the twine material and its diameter, tooth spacing and mesh size. The recent studies show that a hard collection system has better selectivity rather than the soft collecting system like webbing.

It has also been noticed that improving efficiency of the dredges, like in the Canadian waters, has significantly reduced the bottom contact time of the gear, thereby reducing the overall impacts. The different types of dredges and their classification is as follows:

3.1.1. Hand / Manual dredge – with handle, scratcher

3.1.2. Boat dredge/ mechanical dredges – mechanical power used, often to scrape the bottom up to a depth of 60 cm; but automation is not involved

3.1.3. Hydraulic dredge – lot of automation, with regard to harvesting, bringing onboard, sorting and packing. Mostly done using a water jet created by two pipes, one smaller in diameter and the other larger one, mostly by Venturi principle – venturi dredges.

3.1.3.1. Side rig dredges – depending on the deck arrangement and the operation of the dredge

3.1.3.2. Stern rig dredges – dredges that are operated from the stern of the vessel

3.2. Trawling

Trawling contributes significantly to the marine catches in the world and is one of the most efficient methods of fishing. The most significant improvements in the trawling sector, has been the introduction of mechanization, with large, powered engines, capable of fishing for long durations and facilities available onboard for preservation of the catches. However, it is often implicated with generation of large quantities of bycatch and significantly impacting the non-targets groups and the bottom integrity of the sea floor.

Based on the recent estimates of discards FAO (2020), the annual discard quantity in the world fisheries is about 9.1 million tonnes (10.1 percent of annual catches), of which 4.2 million tonnes is from bottom trawls, and 0.9 million tonnes from midwater trawls.

A large number of technologies and simple modifications were attempted in the world fisheries to address the issue of bycatch and also reduce the impacts to the sea bottom by trawlers. Common simple modifications like increasing the lateral mesh opening to match the morphology of the unwanted catches have been tried, so is the turning of mesh direction to allow the mesh to remain open and hence help in the release of unwanted catches from the trawl. In some fisheries, complex grids are often used, and in many temperate waters, this has been successfully implemented.

Bycatch Reduction Devices (BRDs) are a collective term for devices created to exclude endangered species such as turtles and to reduce non-targeted species in shrimp trawling (BRDs). These devices were built with the difference in size and behaviour patterns of shrimp and other animals inside the net in mind. BRDs can be categorized roughly into three types based on the materials used in their construction: soft BRDs, hard BRDs, and combination BRDs. Soft BRDs separate and exclude bycatch by utilizing soft materials such as netting and rope frames. Hard BRDs employ rigid or semi-rigid grids and structures to separate and exclude bycatch. Combination BRDs incorporate multiple BRDs, typically hard BRDs and soft BRDs, into a single system.

In addition to the modification in the size or shape of the codend, design modifications like semi-pelagic trawls, short body trawls, horizontally separated trawls, etc. have been tried with success experimentally, but their adoption have been equivocal, especially in locations where there are no strict legislations and effective monitoring, control, and surveillance mechanisms in place.

Despite many years of work related to making the trawls more selective, generation of bycatch is still a big issue is many trawl fisheries and this is particularly so in the multi-species fisheries around the globe. A recent global review of the studies carried out in bycatch reduction in trawls, point to the fact that despite many studies, about 203 in total, that has attempted many techniques, to reduce bycatch, no fishery has completely resolved all the bycatch problems while maintaining targeted catches at conventional levels.

The different trawling types and their classification is given below, which indicates the complex ways, in which trawling is being conducted and the difficulty in coming up with solutions to the myriad problems that it faces with respect to sustainability. Nevertheless, modifications to the codend are one of the most widely adopted technique and the recent developments in this gear, has been to improve the size selection in this part.

3.2.1. Bottom trawling

- 3.2.1.1. One boat – sailing broadside
- 3.2.1.2. Two boats -pair trawling
- 3.2.1.3. Beam trawls
- 3.2.1.4. Otter trawls

3.2.2. Mid-water trawling

3.2.2.1. One-boat otter trawls

3.2.2.2. Two-boat trawls

3.3. Seine nets

In its simplest form, a seine net is a net wall composed of two wings and a piece in the center to keep the catch (the bunt or bag). The wings are long, and each is lengthened by a long towing line or warp. The seines are basically divided into two major types, based on the presence of a bag or without a bag. Seining operations like beach seining can be thought of as one of the oldest methods of bulk fishing.

However, these techniques are frequently discovered to be fading with time, owing to the fact that seining was traditionally considered to be strenuous labour for a group of men. Now, with human labour wages at an all-time high, practically every seining fishery is slowly getting mechanized. Not only the towing ropes are wound on special winches, but entire wings are also being towed mechanically, mostly with the use of winches and tractors. This has helped in the modification of beach seines to boat seines, the main advantage being the increase in the operational area of the gear. There is however an increase in the size and engine power of the boats used for seining operations.

Nevertheless, with all the developments happening, seining operations remain traditional in most parts of the world, involving a large number of work force and the main investment is the large gear. Compared to trawling, the mechanization in the seine fisheries was late and little, and it remains a low energy operation, and comparatively more selective than trawling. Attempts have been made by use of inboard vessels fitted with winches, to pull the lines, but these have not been hugely successful in the long run. Floating otter boards like Hong kong diverter were also tried, which helps to maintain the webbing and the line in the water column for longer times, thus improving effective fishing times, but these would have increased the resistance and hence were not successful. Similarly, there had been attempts to electrify the head and foot ropes, with power coming from one of the boats used for towing. However, these were also not successful and not practiced now.

In comparison to bottom trawls, the advantages of seining include lower energy consumption and increased selectivity due to the bag's slower movement over the sea floor, which may mean that seining has a brighter future.

3.3.1. Double-stick nets – small nets, without bags held between two sticks

3.3.2. Genuine seine nets – without, and with one or more bags, equi or non-equi winged, with tow line of equal or non-equal length

3.3.3. Beach seines – with or without vessels onto beach

3.3.4. Boat seines – gear hauled in deep water from a boat - The boat seines consist basically of a conical netting body, two relatively long wings and a bag ahead of the wings, are long ropes which are used to encircle a large bottom area with the purpose of herding (catching) fish form that area.

3.4. Surrounding nets

The technique used to capture shoaling fishes in large quantities, by means of surrounding the shoal from the sides and may also from the bottom in case of gear with pursing mechanisms. There are wide variations in the designs and the most of them form either a dust pan shape while in operation or a closed purse, depending on the use of a pursing device.

These nets are widely used in the world fisheries and can be considered as an upgraded version of the seine nets, with a better efficiency compared to their predecessors. Among the mostly widely used surrounding net is the purse seine, which over the years has improved its efficiency in terms of the size of the gear and mechanization, like the use of puretic power block and Triplex. Studies using webbing with high sinking rates like Ultra High Molecular Weight Poly Ethylene (UHMWPE) have been tried and found to be successful experimentally. However, the adoption of these webbings in the fishery particularly in the south east Asian countries has been not so encouraging, mostly due to the high price of new generation webbing. Selective replacement of these high strength webbing in regions, where high damage is found to occur has also been tried experimentally along Indian waters.

Purse seines, like other surrounding nets, are not selective; nonetheless, schools are carefully selected based on the presence of bycatch species (operational selection). Bycatch species are a frequent occurrence during FAD assisted purse seining, with over 40 species of fish and cetaceans reported from purse seine landings. To avoid dolphin capture in purse seines, special escape panels known as Medina panels have been introduced. Medina panels are sections of tiny mesh that prevent dolphins from being entangled in the gear. Purse seine selectivity can also be improved by selecting the suitable mesh size for the target species, as well as by selecting the appropriate fishing region, depth, and season.

Another equally important design that is the ring seines, which is hugely popular along the southern west coast of India. This has evolved from lampara type of nets and since then has seen major changes in the dimensions, which is now almost three or four times, bigger in proportion that it was originally envisaged to. This gear has now completely overtaken the purse seine operations along the south west coast of India and is seen to spread to other states of India. The technology creep has serious implications on stocks, since the increase in the size of the gear, coupled with high powered engines, has quadrupled the efficiency of these gears. It is also reported that this gear contributes significantly to juvenile catches of shoaling fishes like mackerel and sardines.

The major classification of the surrounding net are as follows:

- 3.4.1. Lampara-like nets – without pursing device, but with a shorter ground rope that helps in attaining a dustpan shape to the webbing during the operation.
- 3.4.2. Purse seines – with pursing device
  - 3.4.2.1. One-boat system – with or without skiff
  - 3.4.2.2. Two-boat system – without skiff
- 3.4.3. Ring nets – hybrid between lampara and purse seines, with pursing device

4. New technologies in fisheries

Apart from the technologies particular to each type of gear described, the future of fishing technology will be heavily reliant on the application of high data from satellites and big data from the various types of Vessel Monitoring Systems (VMS) currently in use worldwide. Numerous research articles utilizing AIS data from vessels worldwide have already demonstrated the application of bigdata and its utility. Fisheries management in the future will be dependent on the utilization of big data, sensors, robotics, and the internet of things.

Open sharing of VMS data can considerably aid in understanding fishing vessel movement and also in correlating these movements to ocean biogeochemical cycles, which can open up new paths for fisheries management and conservation.

5. Conclusion

Active fishing tactics account for a sizable portion of the world's total fish catch. While they add significantly to catch, the majority of these active methods of fishing are alleged to be non-selective and to have a detrimental effect on fisheries resources and the biological basis of production. Trawling is one of the most extensively practiced active fishing methods worldwide, and the process of mechanization began much earlier in this sector than in others. This led in design and mechanization advancements, which resulted in a large increase in fishing capacity. The growth in individual fishing capacity, along with the unfettered expansion of fleet size, has made it one of the most despised active fishing methods.

The generation of massive amounts of bycatch, often more than 50% of total catches in some fisheries, is the primary concern, as is the impact on the sea bottom, which has both short- and long-term effects on the ecology.

Making the trawls more selective both in terms of species and size, selection is one of the active areas of research. As a result, a large number of bycatch reduction devices, and also different designs have been developed in the world fisheries. Nevertheless, with all these developments, the issue of bycatch and the impacts of bottom still remain one of the main drawbacks in the case of trawling.

Though the developments have been late and little, the seine sector has also seen advancements, but most of these are often very minute, when compared to the sectors like trawling and purse seines.

Another active method of fishing, which has seen large scale advancements is the surrounding nets, like the purse seines and the ring seines. The advancements like power block, use of triplex etc. have significantly reduced the labour involved in these operations. However, there are issues with regard to capture of large quantities of juveniles of shoaling fishes. However, unlike towed gears, the fishers have the choice of selecting and surrounding the shoals due to the system's innate potential to choose.

While active fishing methods have a considerable negative impact on the environment and require a lot of energy, they are frequently quite efficient and are the most effective method of capturing some species. The primary impact is frequently due to the unchecked expansion of the capacity and fleet size of active fishing gears. Others, such as seining, are still used in their most primitive forms, requiring minimal energy input and remaining among the most energy efficient ways of fish capture.

Effective management measures to rein in capacity expansion and also unfettered fleet expansion are critically needed in some active fishing methods.

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Advances in passive fishing methods

Dr. Saly N Thomas
Principal Scientist,
Fishing Technology Division, ICAR- CIFT, Cochin
Email: salythomas@gmail.com

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 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.

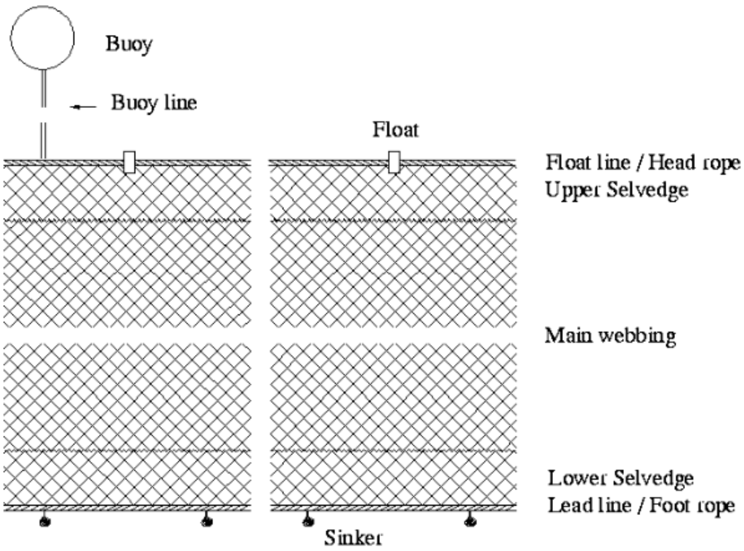
GILLNETTING

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



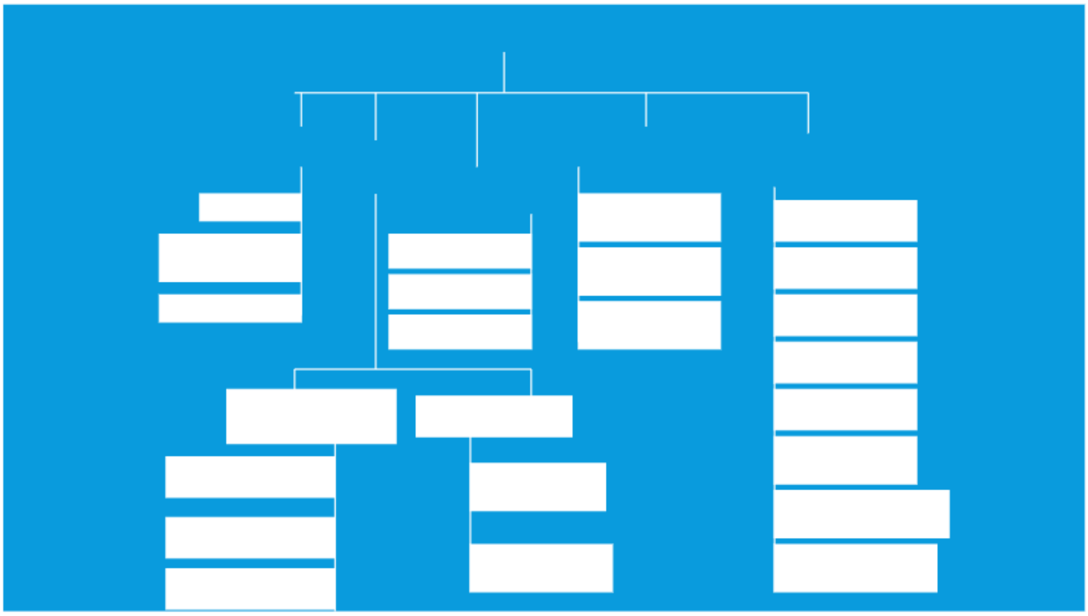
Structure of a typical simple gill net

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 tar get 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 ` ’ ` ’ fish to be caught and catching it.

Advances in gillnetting

Changes in gear material and accessories, method of operation, use of resource specific gear, motorization and mechanization are the major advances happened in the gillnet sector.

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 buoyancyalso have been changed from natural to synthetic materials. Wood/bamboo/cork /glass/aluminium 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 advancement that has happened in gillnet sector is the switch 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

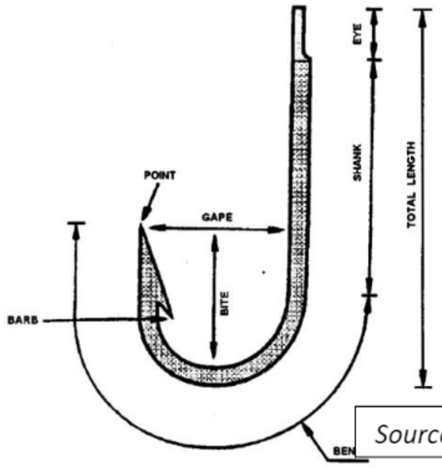
Hook and line fishing is among the simplest of fishing gear and considered as the most ancient type of fishing. In hook and line fishing, fish are enticed by edible natural bait or artificial baits or lures and are held by the hook concealed in the bait. It is a very popular fishing method as it is eenvironment- , q , ' ,
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.

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

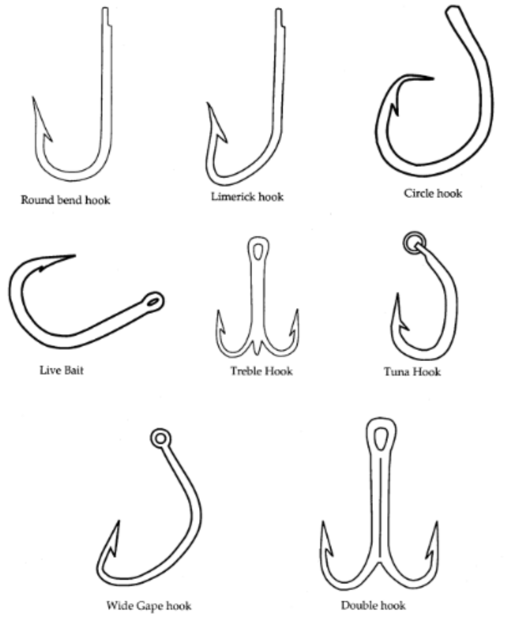
Parts of a typical hook

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.

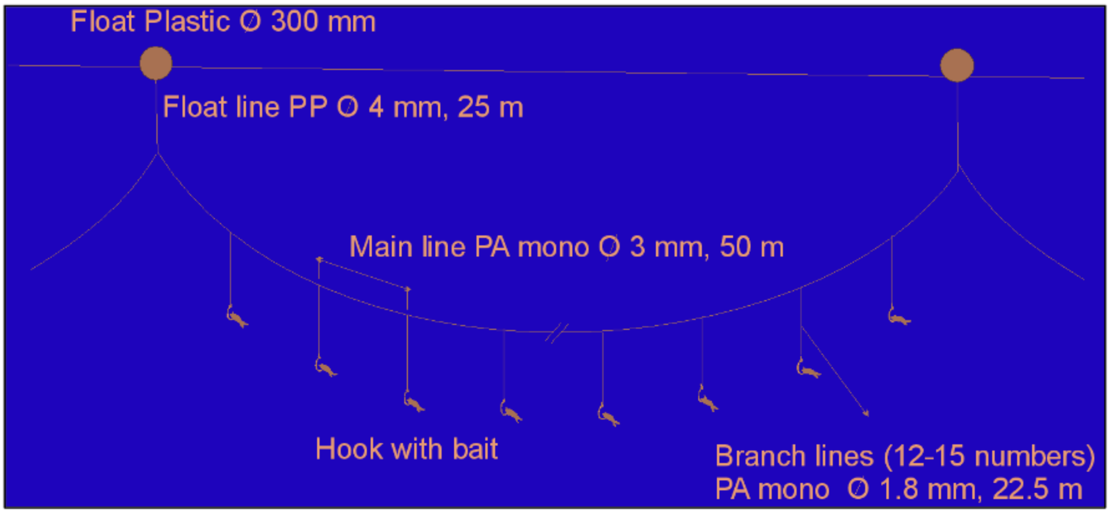
A typical long line consists of a mainline, branch lines/gangion/snood, hook and the bait. Hooks and branch lines can be attached to the mainline by using knots or mechanical crimps or clamps. Buoys, buoy lines, sinkers, swivels and connectors, flag poles, light buoys, radio buoys and radar reflectors 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.



Source: Thomas et al., 2007

Fig. Common hook types



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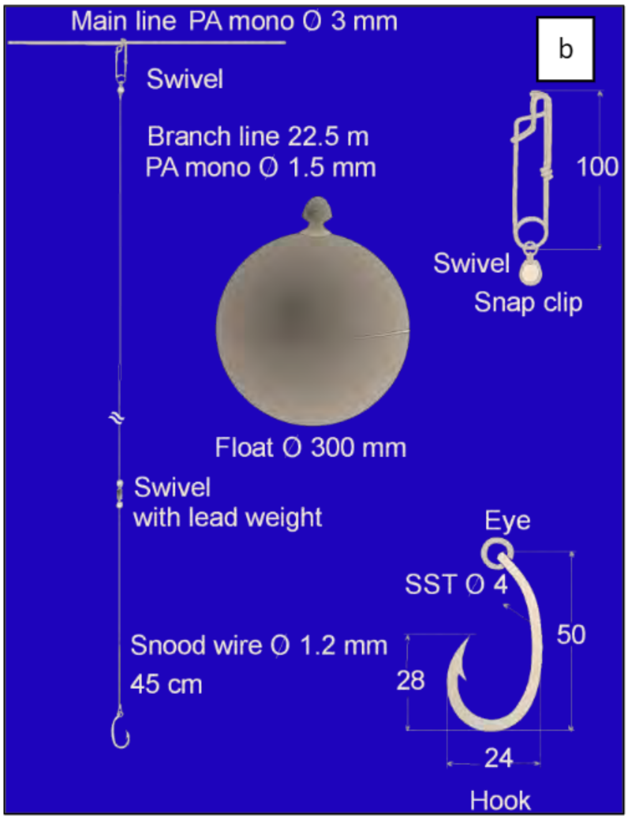


Typical structure of a long line (a) horizontal long line (b) Branch line

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/length 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.

Advances 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 , , j PP, , " " , - high molecular weight polyethylene etc. Fluorocarbon line is a more recent one which is nearly invisible to fish. These fibres are thinner, stronger, shock resistant and durable. Fishing rod: Fishing rod also is changed 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 floats and sinkers also used for line fishing.

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

<u>Shape:</u> 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:

Advances also have taken place in bait technology. Use of artificial soft baits from biodegradable materials avoid pollution due to the loss of plastic lures. Fish attractant compounds `fish scents are used to attract more fish towards the hook.

Motorization & Mechanization: With the advent of mechanization and motorization, fishing effort has been increased in terms of vessel size, engine power, larger gear 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 working of large-scale long lines from relatively smaller vessels than before. Automated long line system consists of a line hauler with a mechanised method of cleaning 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 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 craft. 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. 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, disadvantage of traps is that they are prone to gear loss and ghost fishing.

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 with a mooring system or fixed on stakes. Huge semi-permanent pounds 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 with in lead them towards smaller inner chambers. All except the final chamber are closed only at the bottom while open at the surface. These traps are used in places where considerable tidal influence is there and catch trapped in the pound is collected during low tide. Large-scale traps like the pontoon trap 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 at the terminal end. The fish entering voluntarily find 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 tidal influx is there. 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 staked fixed to the ground or by anchors or weights. A series of nets are set in a line.

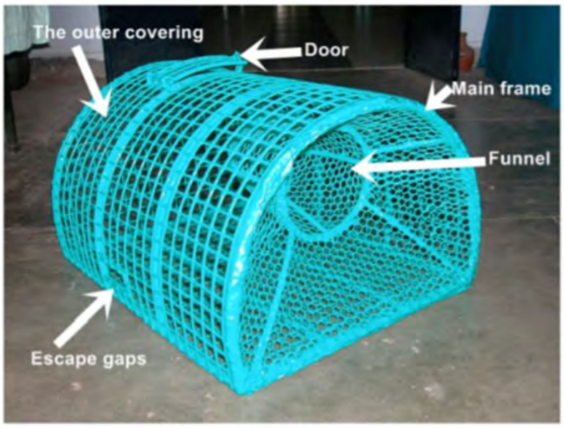
Barriers, fences, and weirs: These are a group of gears operated in tidal waters. Principle of operation is almost similar to pound nets. They have a narrow leader portion ending in a broad chamber in which fish is trapped. It is made of sticks, netting or poles. These are also operated in shallow coastal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

Fish trap, lobster trap, crab pot etc are common. Fish trap is comparatively bigger than shellfish trap. All types of traps are made of a frame made of iron covered with netting. The trap is open on one side and is provided with two consecutive funnels or valves made of webbing 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 individually or sometimes 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 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 ’ 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.

Advances 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.

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 very much size selective.

Timed release mechanism: Ghost fishing is a major problem with lost traps/pots. 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 so that the trapped organisms can escape.

Advances in passive fishing methods have brought out positive and negative impacts on the fishery.

Positive impacts: Introduction of improved materials have resulted in efficient gears, higher catch, durable gears and overall increased income to fishers. Mechanization and motorization enabled in use of 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 incidentally catching non-target species 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.

Conclusion

Largely 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. For this, passive fishing methods which generally are LIFE are to be encouraged. However, the negative impacts of these gears are to be addressed.

Resource and Energy Conservations Measures in Fishing Gears

M.P. Remesan

Principal Scientist,

Fishing Technology Division, ICAR- CIFT, Cochin

mpremesan@gmail.com

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.

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. FAO reported that many of our fisheries are supported by IUU fishing.

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

- Input control-moratorium for new vessels
- Out put control-catch limit
- *Fleet size regulation based on total allowable catch*
- *Regulated access based on licensing*
- *Buyback programs*
- *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

Destructive fishing:

- 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).

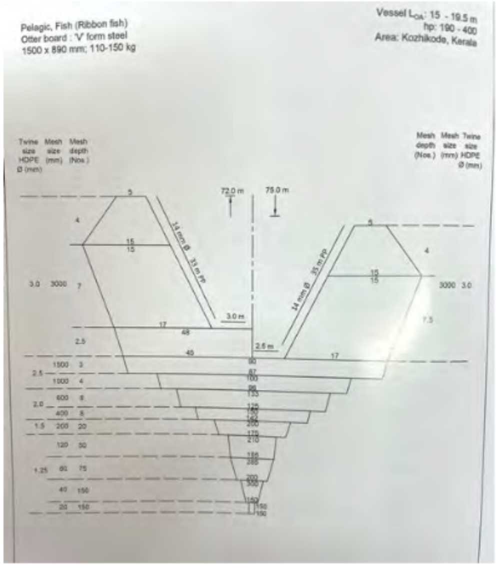


Fig 1. Design of a large mesh trawl

UHMWPE trawls

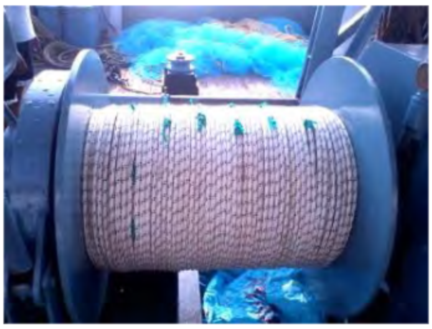
Comparative fishing trials were carried out with 24 m trawls made of HDPE twine and ultra-high molecular weight polyethylene (UHMWPE). Study revealed that average fuel consumption of HDPE trawls was 31.86±1.25 l-h whereas it was 25.31±1.38 l-h for UHMWPE trawl. CPUE were 8.1 kg h-1 and 7.9 kg h-1 for 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.

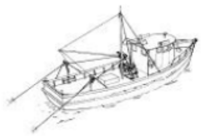
Particulars	UHMWPE trawl	HDPE trawl
Head rope length	24.0 m	24.0 m
Weight of netting	8.0 kg	14.48 kg
Twine size	1, 0.85, 0.75 mm	2, 1.5, 1.25 mm
Drag of the trawl	12.6 kN	14.83 kN

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

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)

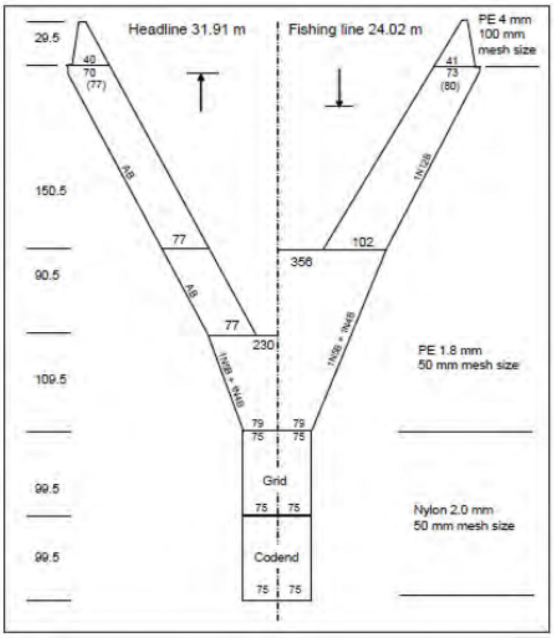
Semi-pelagic trawl

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



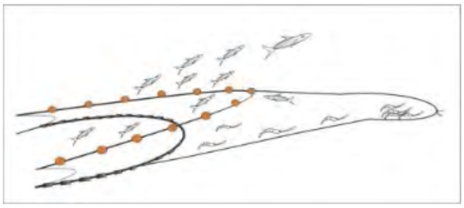


Fig.4 Cutaway top belly shrimp trawl

<u>27m Short body shrimp trawl</u>

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.

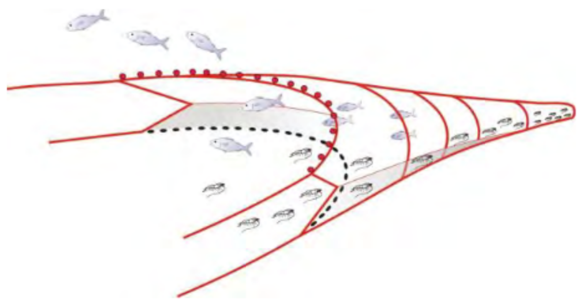


Fig.5 Short body shrimp trawl

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.

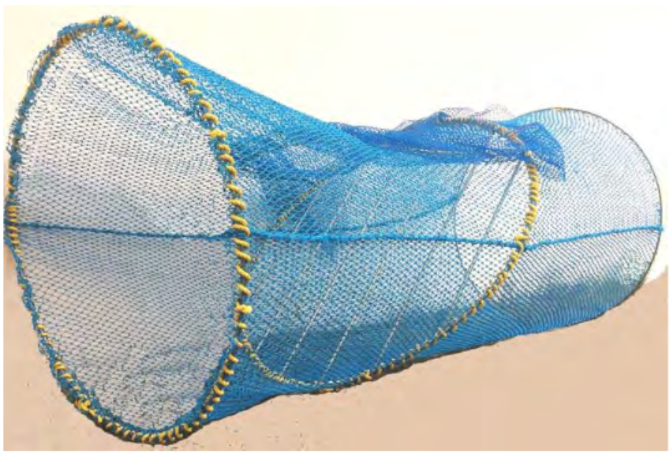


Fig.9. 1200mmx1000mm Turtle Excluder Device

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

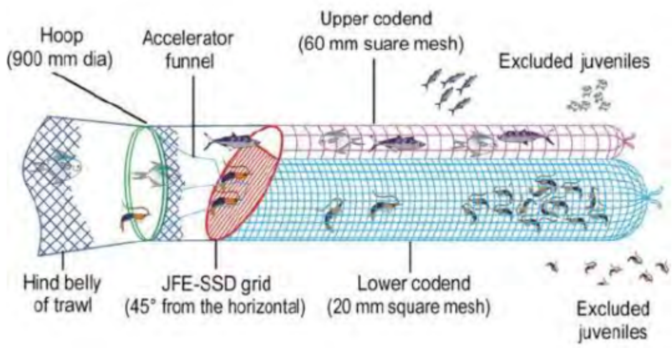


Fig.10 Juvenile Fish Excluder cum Shrimp Sorting Device

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

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

<u>Bycatch in long line fishing</u>

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

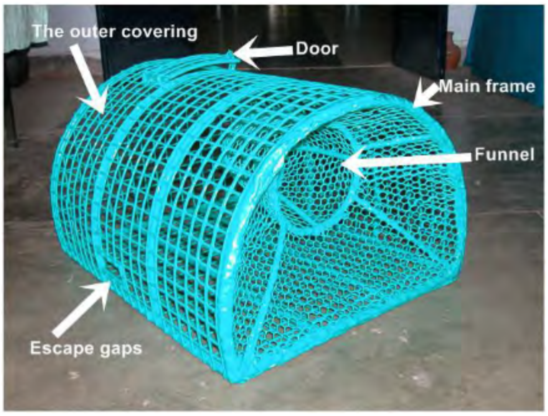
DWN is operated in Kerala, India during March to May to protect ring seines from dolphin bite.

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 and lobster trap



<u>Responsible Fishing Gears and Practices are promoted globally for</u>

- Resource and Energy Conservation,
- Reducing the emission of green house gases
- Minimizing the impacts of Climate Change and
- Sustainable Fisheries for Food, Employment and Income for our survival

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Life Cycle Assessment (LCA): A technique for energy optimisation in fisheries

Paras Nath Jha

Fishing Technology Division, ICAR- CIFT, Cochin

Introduction

Fisheries can be considered as a primary industry which starts at a point of supply chains of local, regional and global significance. It plays a key role in food security due to high protein content of fish and fishery products. Fisheries also act as promising way for employment generator and nutritional security (FAO, 2012). Worldwide about 58.3 million people are directly or indirectly involved in fisheries and aquaculture. Out of which about 37% people are directly dependent on fishing and rest are in other allied activities like processing and marketing. Global human consumption of fish and fishery product rose from 20 million tonnes in 1950 to more than 156 million tonnes in 2012, with total production of about 179 million tonnes (FAO, 2020). All over the world diverse range of fish catching methods with different fishing gears are used by artisanal to mechanised systems.

Fuel use and GHG emission

Fishing operation is an external energy-intensive operation which produces emissions mainly due to burning of fossil fuels (Parker et al., 2018). Other related activities which demand energy input, such as net fabrication, fishing gear operation, post-harvest activities etc. Fossil fuel is a dominant energy sources in different fishing methods such as long-lining, gillnetting, trawling, ring seining and purse seining. Mechanized and motorized fishing operations are dependent on fossil fuels which are non-renewable and releases high levels of carbon dioxide to the atmosphere contributing to greenhouse (H) (Driscoll & Tyedmers, 2010). 40 2011 179 O_2 q (O_2 q) H (P , 2018) In 2016, a total CO_2 emission of the industrial fishing sector was 159 million tonnes compared to 39 million tonnes in 1950 (Gray & Vancouver, 2019). Due to , , emission of GHGs also increased which finally led to (Muir, 2015). The energy and material used in the fishing vessels can create negative environmental impacts, mainly due to the consumption of fuel, gear usage and loss, anti-fouling

agents, paint and ice consumption (Rowe et al, 2010). The use of energy is now increasingly important in comparative resource-use analysis, potential trade trends, and in carbon and related greenhouse gas (GHG) impacts in climate change mitigation (Poseidon, 2011; FAO, 2012). The active cost of fishing is less understood and consequently receives less attention than the direct impact on fishery stock and marine ecosystem (Jha & Edwin, 2019). During the last decade, the price of fuel and other energy sources was on a rising trend. In 2001, fuel was estimated to account for 21% of revenue from landed catch, whereas in 2008 this increased to about 50%. Fuel use varies usually with type of fishing and level of effort, but as one of the key cost components over which the fisheries sector has no direct control. Profitability and livelihoods are potentially highly sensitive to energy costs (FAO, 2015; Muir, 2015). The emissions from fisheries were not given importance as compared to other sectors, however, the contribution of fisheries sector is negligible which roughly may be <1% to global GHG emission (Tyedmers, 2004). Later many studies, research publications and report highlighted its importance (Tyedmers, 2001; Vivekanandan, 2011). During last 3-4 decades several factors played a pivotal role in increased emission viz. increment of fleet size and number (overcapacity), which resulted higher catch (Srinath et al., 2004). The major direct and indirect energy inputs can be systematically analysed using process analysis and input-output techniques. Mostly direct fuel inputs are used primarily for vessel propulsion. On an average direct fuel energy inputs account for between 75 and 90% of the total energy inputs, irrespective of the fishing gear used or the species targeted. Remaining 10 to 25% is generally dependents on vessel construction and maintenance, and the provision of labour, fishing gear, bait, and ice if used which depending on the character of the fishery and the scope of the analysis conducted. The secondary energy-consuming activities, which include on-board processing and storage is negligible compared to primary energy consumption in terms of fuel burned. Here squid jigging is an example in which relatively large proportion of fuel inputs are used for activities other than vessel propulsion. These include mainly batteries of high intensity lamps, automated jigging machines, and on-board storage facility etc. The energy requirement is met by diesel-fuelled generators to attract, hook, and preserve the catch while fishing. On an average the non-propulsion energy demands account for 40% of the total fuel burned. Out of total indirect energy inputs, largest fraction account for building and maintaining the fishing vessels.
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fabricated basically from energy-intensive materials such as aluminium and steel as compared to wood or fiberglass.

Energy requirement in different fishing operations

Based on behaviour and habitat, there are different methods of fish harvest and on the basis of their operation the quantum of fuel and energy requirement also varies. According to the study of Thomson (1980) globally large-scale industrial fishing sector consumed about 14-19 million t and small-scale fishing sector consumed about 1-2.5 million t of fuel oil. The production of fish per tonne of fuel was 2-5 t in the industrial sector and 10-20 t in the small-scale sector. In energy context some of the important fishing methods are listed below:

Trawling: Trawling is one of the most energy intensive fishing methods. It consumed nearly 5 times more fuel compared to longlining and gillnetting (passive fishing methods) and over 11 times to purse seining for every kilogram of fish produced. For large trawlers, 90% fuel consumption accounts during active trawling operation. Percentage of fuel cost in the operational expenditure of trawlers may vary between 45% and 75%, depending on engine power and duration of voyage.

Gillnetting/longlining: Gillnetting and longlining are the passive type of fishing where the gross energy requirement is comparatively lower than trawling. These passive gears are either fixed or drifting in water column which do not require energy for operation process except hauling where it is done by mechanical means.

Purse seining: Purse seining is one of the most aggressive and efficient commercial fishing methods for capture of shoaling pelagic species (Ben-Yami, 1989; Ben-Yami and Anderson, 1985). It is a fishing technique which targets pelagic shoaling fishes. Before actual operation the shoal detection needs more fuel for fish scout, once shoal gets detected the encircling, capture and hauling process is follow-up. Purse seine operations are relatively energy efficient and greenhouse gas (GHG) emissions for small scale mechanised purse seine operations is low compared to trawling, gillnetting and lining operations.

Traps and pots: Traps or pots are gears in which fish are retained or enter voluntarily and will be hampered from escaping. They are designed in such a way that the entrance itself became a non-return device, allowing the fish to enter the trap but making it impossible to leave the catching chamber. It can be baited or non-baited. Generally passive fishing gears like gillnets and trammel nets, tangle nets, longlines, trap nets and pots, and other lift nets consuming very little power in fishing and in some cases no mechanical energy. Although travelling, setting and retrieval of gear may use some energy, target stocks are attracted by bait or are carried to the gear or encounter it by chance and are trapped. Tyedmers (2001) reviewed over an approximately 20-year period (early 1980s to late 1990s) and found about 330 L of fuel used to catch per t of catch in a crab trap.

Other types of fishing: There are several fish harvest practices which require more energy; light fishing is one of them. Fishing using lights has been practiced from historic times, a classic example is 200-year old Chinese dipnet, which use lights (earlier hurricane lamp and now CFL lamps) to attract fish to the net. Chinese dipnets are mostly animate energy based sustainable fishing operation. More than half of the purse-seine vessels, stick-held dipnet and squid jigging boats use artificial light. Report of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB), 2012, suggests that roughly global marine catches using lights is 1.09 million tonnes (1.6% of global catches) in 2010. Roughly 16% of the light fishing catches comprise of squids, and the remaining >80% are fish species (Mohamed, 2016).

Measures for energy optimisation

Energy security and conservation have great significance on account of responsible fishing and also to meet the demand-supply gap of fossil fuel. During the tow, resistance of the vessel is insignificant compared to the resistance of the gear. The gear resistance therefore has a large effect up on overall fuel economy. Fuel cost can be over 50 percent of the total expenses on a fishing trip. Generally fuel consumption due to floats, sweeps, warp, otter boards, foot rope and webbing are nearly 3%, 4%, 5%, 20%, 10% and 58% respectively. Some of the preventive measures can save fuel in trawling operation are use of knotless netting, thinner twine, large meshes, cambered otter boards, optimal angle of attack of otter boards, slotted otter boards, multi-rig trawling, pair trawling etc. The fuel consumption significantly increases at maximum speed of vessel, this is because of increase in wave breaking resistance. Facts established that reduction of 10-20% speed can lead to save fuel by 35 to 61% fuel. Application of proper vessel technology during construction of vessel is very important for energy optimised vessel. Operation at rated engine rpm helps in reduction in fuel consumption. Selection of right engine with proper periodic maintenance is required for effective energy optimisation. For energy optimisation, proper fleet management, resource conservation and fishery-based geo informatics system like PFZ etc are also very important. (Gulbrandson, 2012)

Environmental burden due to fishing

Global Warming Potential (GWP) is one of the environmental impacts due to which quantitatively relate the heat produced by greenhouse gas (CO_2, CH_4, N_2O, chloro-flouro carbons (CFCs), etc.) and traps in the atmosphere. Based on different levels of technological interventions in fishery the attributes of fisheries are different in different parts of world. Residence time of atmospheric gases is assumed to be 100 years. Carbon Dioxide Equivalents (CO_2-Eq) is considered as a standard for calculation of Global Warming Potential (GWP). CO_2 equivalent is a metric measure to compare the emissions of various greenhouse gases on the basis of their global warming potential by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential. Global-warming potential is relative potency of a greenhouse gas, taking account of how long it remains active in the atmosphere. In other words, it is an important indicator in the extent of damage due to environmental degradation by emitting CO_2 in atmosphere. Broadly capture fisheries has three phases; the first involves construction of fishing vessel, gear and other accessories (pre-harvest), the second involves actual fishing operation process (harvest) and the third phase deals with processing and value addition (post-harvest). Out of three phases, harvest phase contributes maximum equivalent carbon emission due to burning of fossil fuel (Ghose, et al., 2014). Carbon footprint and global warming potential (GWP), a sub-set of Life Cycle Assessment is deeply connected to fisheries sector, because of the strong impact on global warming due to emission from boat construction and fuel combustion. The United Nation Framework Convention on Climate Change through its Paris convention 2015 (COP21) stressed the importance of bring down the over-exploitation and pollution for enhanced productivity and ecosystem health of ocean. In this scenario, energy analysis is relevant in relation to fisheries Life Cycle Assessment (LCA) due to the accepted importance of fuel consumption for fleet operations (Tyedmers, 2001) and associated environmental impacts (Thrane, 2006; Schau et al., 2009; Driscoll & Tyedmers, 2010). Globally marine capture landing is almost constant during past two decades however emission by fishing vessel increased by 28% during the period (WRI, 2014). According to one study the larger mechanized boats emitted 1.18 t CO_2/t of fish caught, and the smaller motorized boats (with outboard motor) 0.59 t CO_2/t of fish caught. Among all fish harvesting systems, mechanised trawling is the most energy intensive operation and traditional non-motorised gillnetting is the most energy efficient having the lowest gross energy requirement. Out of non-motorised systems, stake nets have comparatively high energy intensive. Among motorised operations, ring seines have a lower gross energy requirement per ton of fish landed. Gross energy requirement of mechanised seine was found more compared to mechanised seine, this may be due to lower fuel efficiency of outboard motors compared to inboard diesel engines. Fishing operations requires scouting of shoal/search of fishing ground which may be distantly located have relatively high gross energy requirement per t of fish landed.

LCA as a tool for energy optimisation and sustainable fishing

In the fisheries context the one of the major goals of LCA study is to assess the Global Warming Potential (GWP) as the environmental burdens associated with the fishing operations and other allied activity. Conventional fishery research, for a long time, focused mostly on individual stock assessment and management. During the recent past, in some countries research addressed the ecosystem approach to fisheries (FAO, 2003). Many authors studied and reported effect on environment by capture fisheries using life cycle assessment method. Tyedmers (2001), Ziegler *et al.* (2003), Thrane (2004, 2006), Ellingsen & Aanondsen (2006), Vázquez-Rowe *et al.* (2010a and 2010b), Ramos *et al.* (2011) and Svanes *et al.* (2011). LCA is one of the tools which address the increasing concerns regarding energy use/optimisation, inherent in the fishing and associated activities and the need to understand and minimise these impacts. LCA allows for comprehensive evaluations to be made on environmental impacts due to fishing over their whole life cycle and how to reduce at step to step. Environmental impacts resulting indirectly from fishing operations are mostly associated with the extraction and transformation of natural materials and fossil fuels used for the construction, use and maintenance of fishing units. In other words, is a widespread framework for environmental assessment of fisheries with multipurpose impact assessment tool across the globe. It has emerged as a commonly used and suggested framework to workout environmental impacts due to process or product which leads to new insights to environmental impact of processes or products (Ziegler et al., 2016). LCA takes into account of all related activities to provide idea about CO_2 emission due to construction of fishing boats (Thrane, 2006). It is a progressive four step process viz. goal and scope, definition, inventory analysis, impact assessment and interpretation of results. LCA was introduced in fisheries and aquaculture during 2000s and is now popular worldwide. LCA is systematically describing and quantify the range of environmental impacts associated with the industrial aspects of fishing (Hospido & Tyedmers, 2005). Many authors reported effect of marine capture fisheries on environment using life cycle assessment method, *viz*. Tyedmers (2001), Ziegler et al. (2003), Thrane (2006), Ellingsen &

Aanondsen (2006), Ziegler & Valentinsson (2008), Vázquez-Rowe et al. (2010a and 2010b), Ramos et al. (2011) and Svanes et al. (2011). This methodology is standardized for evaluating the environmental impacts of a process/product from its entire life span which is standardized by ISO 14040 and 14044. It is widespread framework which takes an account of entire spectrum of energy consumed in each process/production stage of the material usage. Life cycle inventory (LCI) involves the collection and computation of data to quantify relevant inputs and outputs of a product, process or system, including the use of resources and emissions to air, water and soil associated to the system (ISO 14040, 2006). Several LCA software packages are used for analyzing foreground and background systems inventories along with midpoint impacts of the different inputs by means of ReCiPe 2016.

Important approaches in LCA

The Consequential Approach: The consequential approach to allocation is the theoretical model to deal with multifunctional processes and recycling. However, one need to make a lot of

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construction of fishing vessel to prepare the recipe of curry. Here fish processing waste can be used as supplements of animal feed, and their co-production means the impact of producing other sources of animal feed is avoided. After the curry is consumed, recycling of the empty packing material can mean the impact of virgin packing material production is avoided. This approach forces to make assumptions about quality, viz. do the other sources of animal feed have the same function/quality as the raw fish (in terms of nutritional value), and does the recycled packing material have the same quality as the virgin packing material?

Physical Allocation: In order to avoid such assumptions and concentrate on the life cycle of the fish curry itself, we can choose an attribution approach. In the case of multifunctional processes, one first need to classify the outputs as waste, recyclable material or marketable co-products. Then to determine an allocation key for the marketable products. This can be based on physical characteristics, such as mass, dry mass, volume, energy content and energy input associated with each co-product.

Economic Allocation: As physical allocation can be considered unfair for lower-valued by-products. To overcome this, it is common to use the price of the product and by-products to calculate the allocation keys. Although prices are often confidential and volatile; for this average price over several years can be used.

Allocation at the point of substitution: Fish processing waste are not a typical by-product, because they would be in different forms, depending on dry matter percentage. Straight from the pre-processing, waste is rather wet and have very little market value, therefore it is better not to allocate any burdens to the processing waste and only attribute the burdens from process of making recipe of curry. This approach is called allocation at the point of substitution.

Recycled content or cut-off approach: The most common approach for above situations like the wet processing waste and used packaging material is the recycled content or cut-off approach. This model allocates burdens at the point where a product is sold and applies a cut-off at the point the recyclable material leaves the product system.

Closed-loop Scenario: One situation if there is a great demand for recycled packaging material and there is limited supply also, in that case use of material will be less because of the limited availability at the production site. In this context If we apply recycled content approach, the packaging material would get a large burden from using virgin packaging material. In such situations, several LCA and carbon footprint specifications allow us to apply a closed-loop scenario. This means we assume that all the packaging material that was recycled will be used for the same purpose again. The percentage of recycled packaging material for making the packets is assumed to be equal to the percentage of packets that is recycled at the end of the life of packaging material.

Conclusion

In an ideal situation, generally we use the consequential approach. Then we can discuss our assumptions about which product is actually substituting which product in practice, rather than endlessly disagree on the allocation methods and recycling formulas we are using. Life cycles are complex and full of multifunctional processes and recycling. It takes a lot of time to go through all the options, collect the additional data of substituted life cycles. With the help of LCA technique we can determinate the energy requirement/use at each and every step in a product development or any processes. Subsequently we can reduce/minimise the quantum of that particular step in order to minimise energy consumption. LCA can account for more than just greenhouse gas emissions. In fact, this method allows consideration of other broad but significant environmental impacts that are often overlooked in other methods including toxic emissions released by food production systems such as antibiotics and pesticides, and the use of limited resources such as freshwater and oil.

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“ ” , ( ) (sions) within the system. Thus allowing identification of stages within the system with the highest environmental impacts specially energy requirement and its optimisation.

With a growing number of LCA studies focused on seafood, new insights of current understanding of sustainability is rising. For example, the amount of fuel used to harvest an overfished stock is significantly greater than that for an abundant stock due to the extended amount of time needed to find enough fish. The type of gear used to catch fish can also make a notable difference in fuel use. Even the energy source itself is an important thing to consider, i.e. whether it comes from fossil fuels or renewables. LCA is useful in that it actually considers all of these considerations, thus amplifying our understanding of the environmental impacts of seafood production. So LCA can be used as a technique to reduction/optimisation of energy use in pre-harvest/harvest/post-harvest. Ideally standardised fisheries LCAs, should contribute to better decision making on fisheries management and seafood consumption. The decrease of environmental impacts produced by marine fisheries depends not only on technical improvement aimed at reducing adverse effects of construction, use and maintenance, but specially on the management of the fishing sector in order to decrease fishing effort on overexploited stocks and limit fishing and processing overcapacity. For instance, some of the driving factors of fuel use per landed catch, namely the selection of fishing gear and the size of fishing units, depend on design/management decisions that should be addressed by fisheries policy and management.

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Nano Technology and its Applications in Fisheries

Muhamed Ashraf P

Principal scientist, Material Science and Marine Pollution

Fishing Technology Division, ICAR- CIFT, Cochin

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
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H “ *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
” z
the last decade has tremendous advancement in nano research. Governments and private sectors of the world invested huge sums to reap the benefits from novel applications of nano materials.

Nanotechnology:

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

Classification of nano materials

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

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

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

Carbon nano materials

The fullerene was discovered in 1985 by Robert Curl, Harold Kroto and Richard Smalley [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.

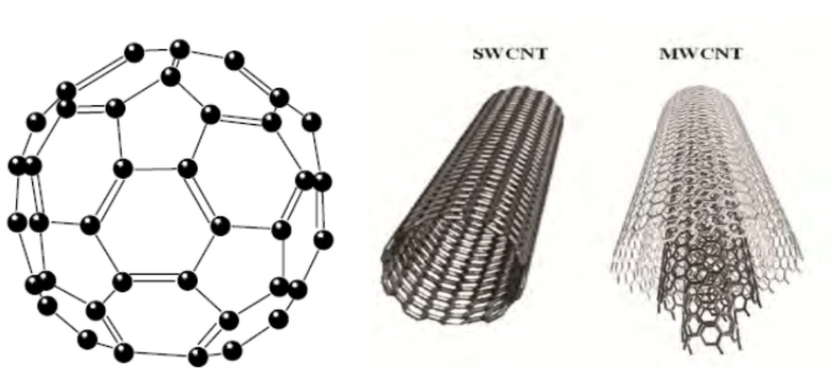


Fig 1. A) Fullerene C60 molecule B) SWCNT and C) MWCNT.

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 “ ” (, , structure blocks etc). Here we have to identify the desired material in advance. The carbon nanotubes are synthesised by passing simple carbohydrates (eg acetylene) through a volume containing catalysts at a temperature of 600 – 800ºC. CNTs are formed on the catalysts [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.

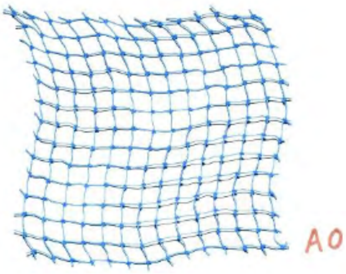
Characterisation of nano materials

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:



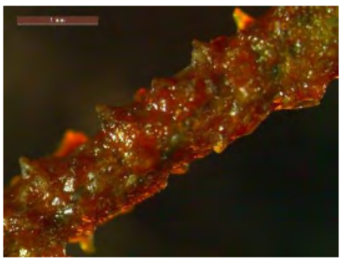


Fig 1. A) PE cage net b) PE cagenet after 3 months c) PE cagenet treated with PANI+nano CuO after three months exposure in the estuary.

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.

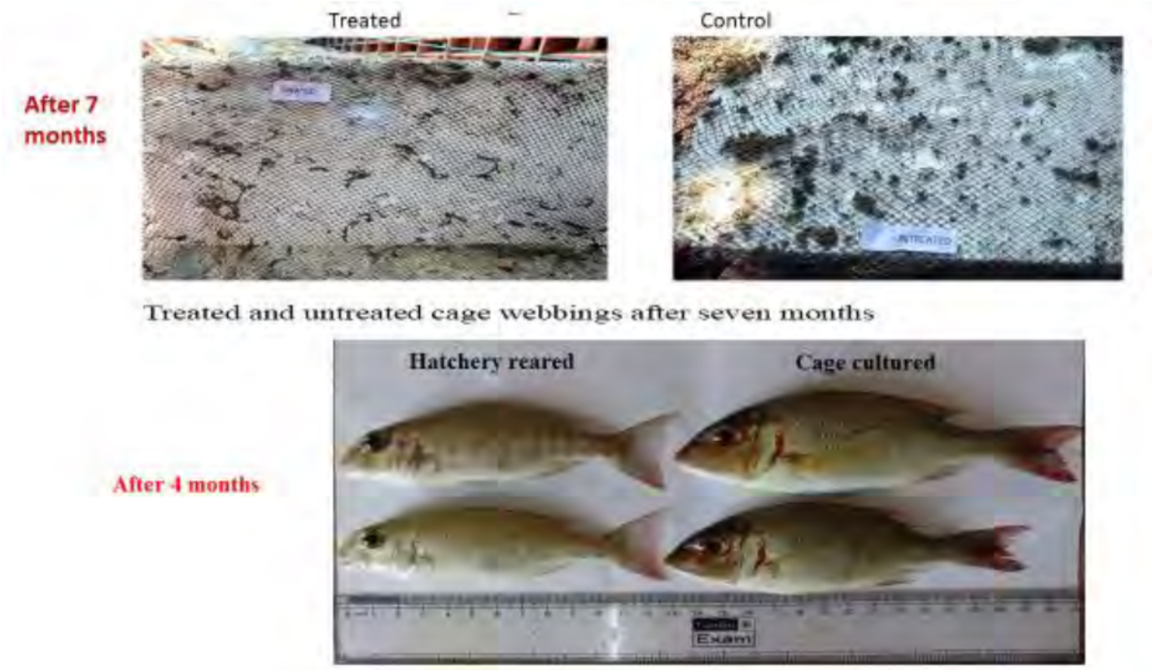


Fig 1. Control and treated net after 7 months exposure in the marine environments.

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 is 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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Fishing vessel design & application of alternate energy in fishing

M.V.Baiju
Principal scientist
Fishing Technology Division, ICAR- CIFT, Cochin

Introduction

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

Design and construction of fishing vessels

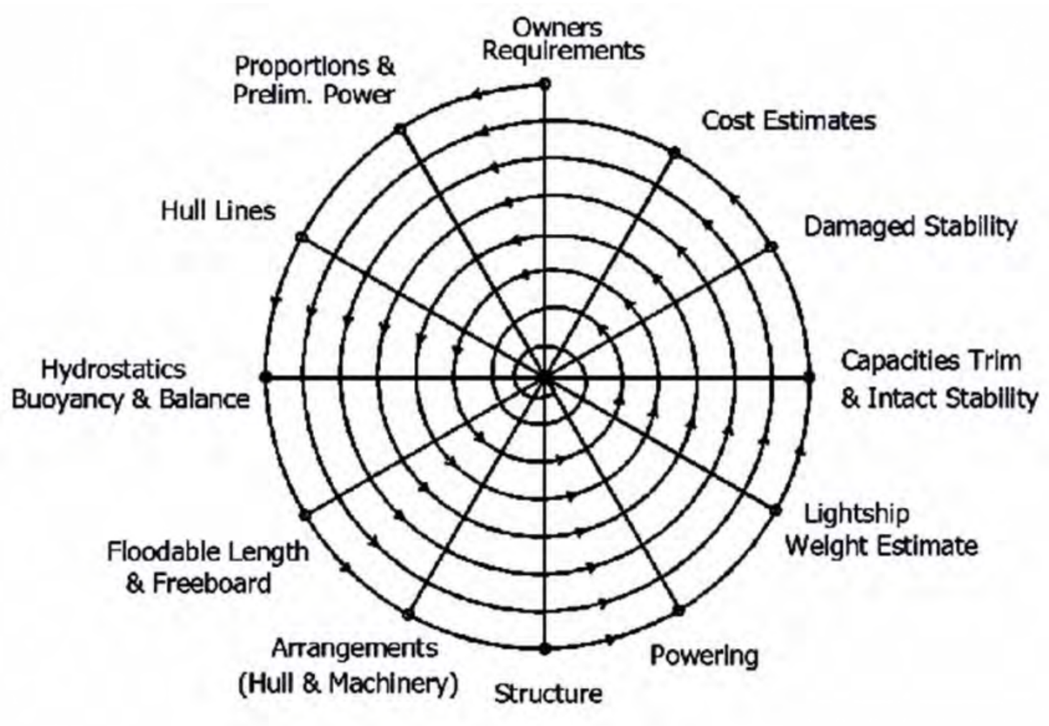
The sea going boats and ships are designed and constructed based on the rules of the classification societies and the registering authorities of the flag nation. This ensures the structural and operational safety of the vessel as well as the crew, cargo and other items onboard. Class or National Standard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

Types of fishing vessels

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

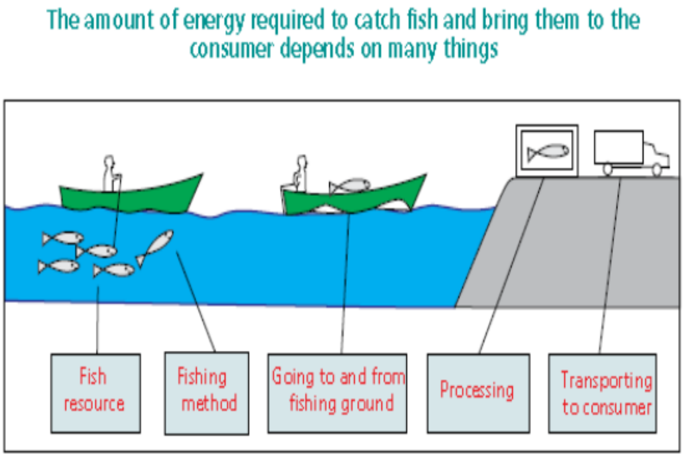
Design of fishing vessels

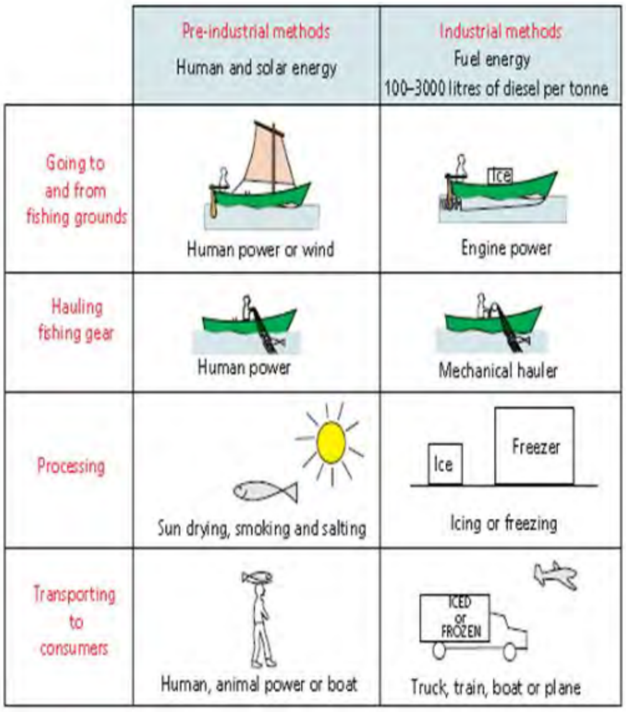
The commercial fishing vessels, are to be designed and constructed based on standard ship building procedure. Design starts from the ’ requirements. Then the preliminary lines plan, offset table, hydrostatic particulars, structural drawings and resistance calculation are done. The structural design is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



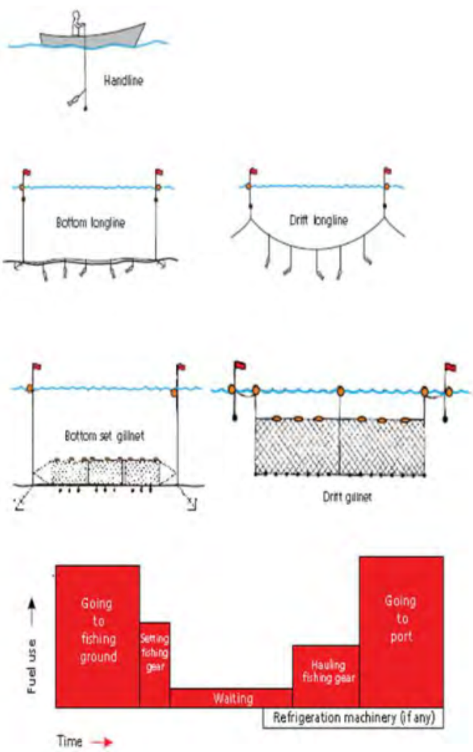
Energy use in fisheries

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

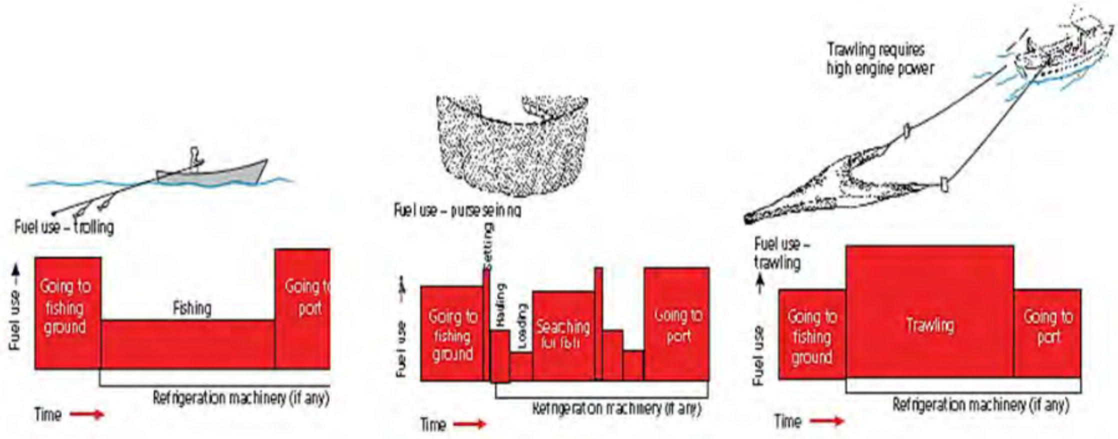




There are two fishing methods such as passive and active fishing methods.



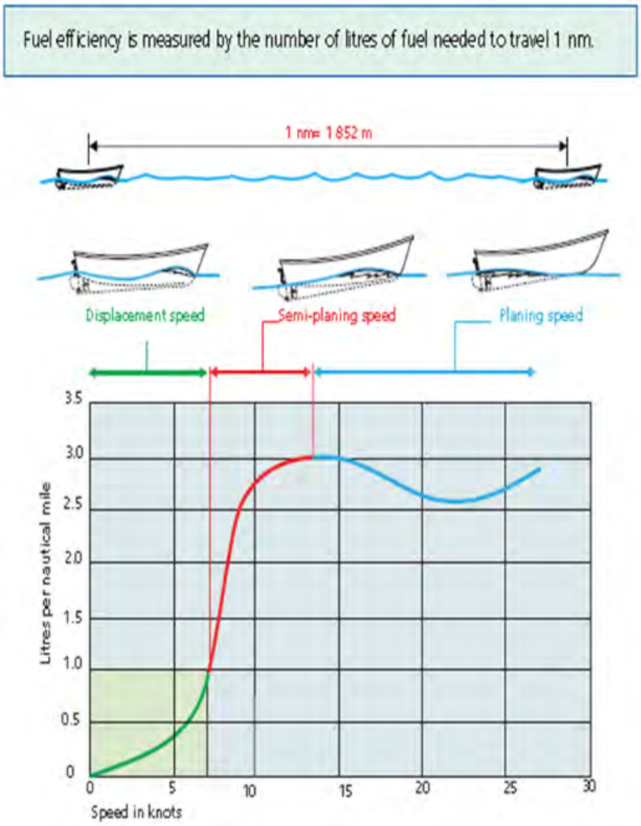
Passive fishing



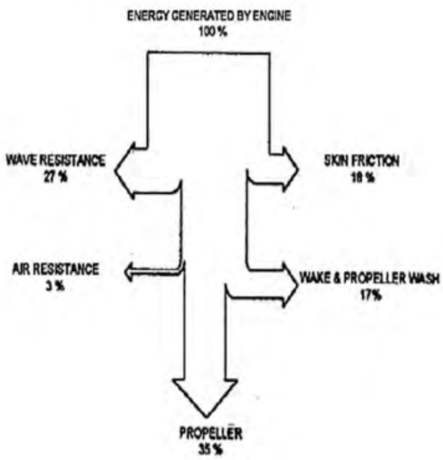
The above are active fishing methods.

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

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

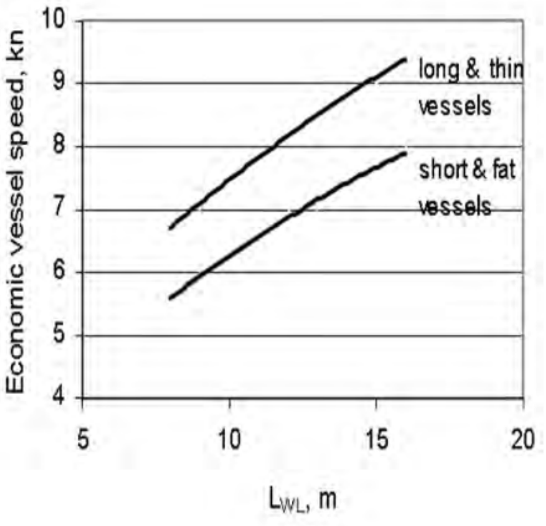


Energy losses in a small trawler when not dragging are indicated in Figure below.



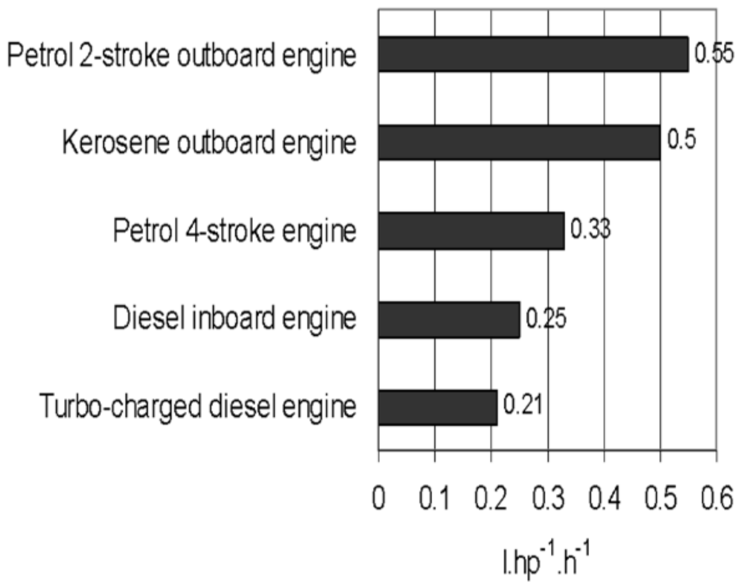
Energy efficiency can be achieved by designing fuel efficient hull form, making efficient propulsion system, optimum size of vessel, setting optimum speed of operation, following operational control for fuel efficiency, combination fishing in one vessel, energy efficient fuel, making bulbous bow for fuel economy, minimise the energy loss from the engine: reduction gear shaft, propeller and appendages and using ecofriendly materials for construction. An efficient propulsion system can be achieved by selecting a proper main engine power and rpm, reduction gear ratio, shaft diameter, length of shaft and making a Kort nozzle for trawling. Optimum size of vessel means the main dimensions are to be fixed for the maximum utilisation of space and minimising the waste. The Length Over All, Breadth, and Depth and Draft are to optimum. Optimumising fish hold volume, space for engine room, accommodation and wheel house helps in fuel conservation. Over speed will attract higher fuel consumption and operational expense. Also lead to more maintenance on engine, gear box and higher level of pollution. Minimising unnecessary idling at harbour and sea, unnecessary use of generator, fans, lights, etc will improve fuel efficiency. Keeping log book and making entry to know the daily fuel consumption will help in knowing the fuel use.

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



Reduction in power requirements can be achieved by (i) increasing length of water line (LWL) and (ii) reducing displacement wherever possible at the design stage, and (iii) by taking measures for control of hull fouling. For normal economic speed the ratio between the vessel speed ( ) ( ), /√

By increasing length of waterline while keeping the other dimensions same, it is possible to reduce the hull resistance and increase the speed. Increase in construction cost has to be balanced against fuel saving advantages. Trials in Norway, Denmark and India have indicated 15 to 20% reduction in hull resistance by modifications with bulbous bow.Reduction in displacement also contributes to lower fuel consumption. Hull built of aluminium, FRP and plywood will be lighter than that of steel, ferro cement and conventional wood construction. 23% reduction in fuel is reported for a 12.5% reduction in weight of small vessels. Fuel saving advantages in such cases has to be balanced against a possible reduction in stability, sea kindliness and cost of the vessel. Fuel consumption due to fouling could increase by 7 percent at the end of first month 44 percent at the six months and 88 percent at the end of 12 months (Gulbrandson, 1986). Hence periodic hull cleaning and application of antifouling paints can lead to considerable savings in fuel. The fuel consumed by different types of engines arte explained below.



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

Right sizing the installed engine power

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

Energy efficient fuel

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

Next is solar power. These two can be utilized well for propelling inland fishing boats. There is no atmospheric pollution from solar boats. The noise level is also very low. Fuel cell, Nuclear are also less polluting but very expensive. LNG has been successfully experimented in marine vessel propulsion. Diesel engines produce high thrust are the most widely used fuel in this sector. Foe small scale fishing petrol engines are utilised. A combination of kerosene and petrol in outboard engines are also popular in some countries. Diesel and petrol engines produce high pollution.

Materials of vessel construction

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

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Environmental impacts of fishing and mitigation strategies

Leela Edwin and Yasmi V S

Fishing Technology Division, ICAR- CIFT, Cochin

Introduction

For centuries, humans have depended on the ocean for their existence by harvesting its abundance of fish. In recent decades, new technologies have allowed humans to remove fishes from the ocean on a massive scale to supply the earth's mushrooming population. The world fishing fleet consists of 4.56 million vessels, of which 2.86 million are motorized vessels and 1.7 milloin are non-motorized vessels (FAO, 2020). The marine fisheries resources of India are in terms of 8129 km long coastline, 0.5 million sq. km of the continental shelf, and 2.02 million sq. km of exclusive economic zone contributed by major fish species like oil sardine, mackerel, Bombay duck, pomfrets and shrimp. The marine fishing fleets of India have a total of 0.25 million fishing vessels consisting of 64,760 mechanized boats, 1,22,951 motorized boats and 65,219 non-motorized vessels were operating along the coastal area. The fisheries sector of India provides employment and foreign currency to millions of people. Around the same moment, it is an instrument of life for a wide section of socially backward people of the country (Ayyappan & Diwan, 2006).

There are many issues within the fisheries sector that requires urgent attention including excess capacity in fishing and need for standardization of fishing systems, operational impacts of fishing (bycatch and discards), increasing energy use in fishing, Issues related to synthetic webbing materials, alternate materials for fishing vessels, marine plastic pollution, minimal monitoring, subsidies, continued poverty within coastal communities and impacts of the globalized fisheries trade. The failure of development agencies to adjust their strategies to this new paradigm will have significant social consequences. These include the loss of economic opportunity and food resources for millions of people living in fishing communities, and the loss of national revenues.

Excess capacity in fishing

Fishing capacity is the ability of a stock of inputs (capital) used in fisheries to produce output, measured as either effort or catch, over a period of time (FAO, 1998; 1999a;2000; 2001). Excess fishing capacity has been identified as one of the most inimical problems affecting economic viability of fishing operations and long-term sustainability and biodiversity of fishery resources (Boopendranath, 2007). In Indian Exclusive Economic Zone (EEZ), the marine fishery potential is estimated at about 3.93x106 t. About 58 % of the resources is available at a depth of 0-50 m, 35 % at 50-200 m and 7 % from beyond 200 m depth. In India, the marine fishing fleets consists of non-mechanized (artisanal) sector using country craft and traditional gears, motorized sector using traditional craft with outboard motor(s) (OBMs) (9.9-120 hp) and, more recently, inboard engines (IBM) (89-156 hp); mechanized sector (8.5-16.7 m L_{OA}; 89-156 hp; and deep-sea fishing sector (>16.7m L_{OA}; 156 hp and above) (Boopendranath, 2007). The current existing number of fishing vessels in mechanized sector is 64760 and 122951 number of fishing vessels in motorized sector, which is more than 19048 number of mechanized fishing vessels and 14862 number of motorized fishing vessels of recommended fishing vessel capacity. The present fleet size of India is collected by CMFRI, 2010 for Indian shelf waters (excluding islands) were 35228 mechanized trawlers, 2201 mechanized purse seiners, 20257 mechanized gillnetters, 11794 mechanized bag netters (dol-netters) and 3079 other mechanised boats which are the excess capacity than the optimum fleet size estimated by Devaraj and Kurup (2000).

Unfortunately, there are many pessimistic environmental consequences to different fishing practices and overfishing has been identified as a primary cause of ecosystem collapse in many aquatic systems. Globally, fisheries are regularly overfished and overexploited as a result of weak governance, poor management, perverse subsidies, corruption, and unrestricted access. In addition, destructive fishing practices can rapidly degrade marine ecosystems and contribute to the loss of critical habitats and species. The declining state of fisheries resources will have disproportionately heavy consequences for developing countries. A recent World Bank study indicates that the fisheries sector is losing an estimated US$50 billion annually in lost revenues due to poor management and from illegal, unreported, and unregulated (IUU) fishing.

Operational impacts of fishing

Disturbance to the sea bottom

Trawl is a non-selective fishing gear creating plowing effect on the sea bottom leading to the destruction of benthic ecosystem. Trawl operated on flat sandy/muddy bottom, the sediments might be whirled up into the water masses and suspended. The major negative impact of bottom trawling is the capture and discarding of huge quantity of juveniles of fishes and other aquatic organisms like turtles. Bottom otter trawls interact physically with the bottom sediment, which might result in removal or damage of sedentary living organisms (including seaweed or coral) and in the case of uneven bottom surface displacement of stones or other larger objects (Remsan & Renjith, 2017). In bottom trawling, the trawl is pulled across the seafloor to catch bottom-dwelling fish, decreases the biomass and production of benthic species. The practice also destroys corals, oysters and sponges that form productive marine habitats (Hiddink et al., 2006).

Dredging is one of the habitat devastation practices commonly affecting the sea floor organisms when the large metal scoop drags along the seafloor to pick the clams. The process also churns up sediments along the seafloor, causing them to become suspended in the water column, decreasing water quality. The practice can also dig up burrowing worms from the sediments. These animals are important because their burrows increase contact between sediments and the water (Thrush & Dayton, 2002).

Bycatch and Discards

Trawl nets due to their low selectivity and high efficiency are often implicated with generation of large quantities of bycatch (Madhu, 2018). Globally, shrimp trawling contributes to the highest level of discard/catch ratios of any fisheries, ranging from about 3:1 to 15:1, and the amount of bycatch varies in relation to target species, seasons and areas (EJF, 2003). Midwater trawl fisheries targeting small pelagic are reported to have the least discards among the different trawling systems. Trawl fisheries for shrimp and demersal finfish account for over 50% of the total estimated global bycatch (Madhu & Jha, 2017).

ICAR- CIFT has developed bycatch reduction devices such as Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD), square mesh codends, Big eye BRD, Fish eye BRD, Sieve net BRD, Oval grid BRD and CIFT- TED are for the sustainability of fisheries. The JFE-SSD is an International Smart Gear Prize -2005 winning design (WWF, 2012), which brings down the bycatch of juveniles and small sized non-targeted species in commercial shrimp trawl and at the same time enables fishermen to harvest and retain large commercially valuable fin fishes and shrimp species (Boopendranath et al., 2012). Square mesh codends significantly reduces the bycatch often comprising of the juveniles of commercially important species. In trawl net, use of square mesh codend is benefited with good filtration and reduction in the drag of net.

Big eye BRD is a simple device constructed by making a horizontal slit in the upper part of the codend or hind belly, where the opening is maintained by means of float and sinker arrangement or binding with twine. It is constructed by making a slit on the top of the shrimp trawl codend by cutting a required number of meshes in the twine – wise direction to obtain an opening of about 0.3 m stretched length, across the codend, on the top panel positioned at about 1.5 m from the distal end of the codend. The slit is kept open by means of sinkers and 2-4 floats of sufficient extra – buoyancy. (Boopendranath et al., 2012). The bycatch exclusion from big eye BRDs was about 11.4 -37.3 % and shrimp loss were 2.3-4.1 %.

Fish eye BRD is an important bycatch reduction device facilitating the escapement of actively swimming finfishes which has entered the codend of trawl. It consists of an oval shaped rigid structure with supporting rigid frames made of stainless steel or aluminum rods. Fish eye BRD is 300 ×200 mm semicircular exit of horizontal orientation, fabricated using stainless steel rods of 6 mm dia. Bycatch exclusion rates of 46.6% - 62.7 % with a shrimp loss of 0.8-3.8% obtained from this BRD.

Sieve nets (also known as veil nets) are cone shaped nets inserted into standard trawls which direct the unwanted bycatch to an escape hole cut into the body of the trawl leading to a second codend. The large mesh funnel inside the net guides the fish to a second codend with large diamond mesh netting, while shrimp pass through large meshes and accumulate in the main codend. It is reducing the bycatch rates of 15-50% with shrimp loss of 5-15%.

Oval grid BRD is a rigid grid sorting device developed for separation of shrimp from non-shrimp resources and its catch exclusion rates of 57.8 -58.7 %, with a shrimp loss of 6.1-8.0 %. It consists of an oval grid of 1000×800 mm size, made of stainless-steel rods with grid bar spacing of 26 mm. The grid has one or two horizontal bars attached to provide additional strength to the grid, which also reduces the flexibility of bars thereby maintaining constant bar spacing.

Turtle Excluder Device (TED) is a specialized form of BRD designed for saving sea turtles caught incidentally during shrimp trawling. CIFT has developed an efficient indigenous TED design for commercial shrimp trawling which offers 100% protection to sea turtles with minimal catch loss. CIFT -TED consists of a 1000x800 mm oval frame and is constructed of 10 mm stainless steel rods. Five 8 mm stainless steel rod vertical grid bars are welded to the inside of the oval frame. The distance between the deflector bars is 142 mm and there is a maximum distance of 90 mm between the frame and the adjacent deflector bar. In the TED extension, the frame was fixed at an angle of 45° before the cod end of the trawl net. The device could be manufactured and installed at a cost of about Rs.4000 with minimum training using locally available workshops and net making skills (equivalent to about USD 90) (Boopendranath et al, 2010).

Purse seine is a large wall of netting deployed around an entire area or school of fish. Purse seining is one of the most advanced type of fishing for catching fish shoals. Most fuel is used for purse seining is going to and from fishing grounds and searching for the fishes. The catch effectiveness of purse seine depends on its length, depth, sinking speed, net type, hanging ratio, and the skill in operation. Among which the sinking speed is one of the most important components influencing the catch efficiency. In tuna purse seine fisheries, the purse seine caught tuna shoals at the sea surface, including bycatch species like flocks of birds, cetaceans and whales (Escalle et al., 2015). The purse seine fishery in the Indian ocean is responsible for 0.15% of the fishing mortality of sharks, 0.16% of whale sharks and 0.3% of marine turtles (Garcia & Herrera, 2018).

The CIFT developed and introduced a mini purse seine which came to be known as ring seine, for operation from traditional plank-built canoes (*Thangu vallom*) powered by outboard motors for efficient harvesting of pelagic shoaling fishes. Widespread operation of these ring seiners along Kerala, Karnataka and Goa coasts especially from the eighties had a profound influence on the marine fish production. Edwin (1997) conducted detailed investigations on the catch and effort, energy utilization pattern, gear selectivity, economic efficiency and management aspects of ring seine fishery of south Kerala coast.

Gillnets are low energy fishing gear which are extensively used in the traditional, motorized and mechanized sectors. Mesh size is the most important factor determining gillnet selectivity. Gillnets are considered one of the best gears in terms of size selectivity, species selectivity is quite poor, catching various species and sometimes entangling marine mega fauna and protected species. A high levels of tuna bycatch is occurred in drift gill net results a gradually depletion of tuna fish stocks is another negative impact of gillnet fisheries. Entanglement in massive fishes such as sharks, whale sharks, and dolphins causes gear loss and its destruction. Gillnet depredation and spoilage is caused by a long soaking period of more than 7 hours. The incidental catch of turtle is reported by using of large meshed drift gillnets is a major environmental issue in mechanized fishing sector (Sherief, 2016). Bycatch of sea birds and entanglement of marine mammals by gillnets have resulted in their negative image in the public. Seabird bycatches are common in almost all gillnet types, especially those set near the surface, adjacent to bird colonies, and in shallow waters.

Longline fishing is one of the most significant commercial fishing method practiced in the all-around the world. By catch is higher in longline fisheries in the Indian ocean than in pole and line and purse seine fisheries. By catch includes 87 species or species groups, including sharks, sea birds and turtles, all of which are categorized as vulnerable or endangered by the International Union for Conservation of Nature (IUCN) (Ardill et al, 2013). From Indian EEZ, the incidents of killer whale and shark depredation in longline fishery has been reported by Chinnaduari et al. (2018).

Ghost fishing and ALDFG

Ghost fishing is an issue directly dependent on the choice of non-biodegradable type of synthetic materials. Abandoned, lost or otherwise discarded fishing gear (ALDFG) has always been happening during fishing, became an environmental issue for the use of non-biodegradable synthetic fibres mainly includes poly amides. One of the reasons for ALDFG to occur is the use of very low-quality modern fishing gears. Use of low-quality netting material gives chances of more material to be lost in sea and other water bodies when entangling with obstructions or in rough weather (Thomas & Sandhya, 2019). The ghost fishing happens when some passive fishing gears like gillnets, trammel nets, pots and traps are lost or discarded but continue to catch commercially important fish and crustacean species as well as non-commercial species of fishes, crustaceans, birds, marine mammals and marine turtles. The lost gear may also continue damaging benthic habitats through abrasion, plucking of organisms, the meshes closing round them causing translocation of sea-bed features and posing problems as a source of litter or entanglement for birds and mammals when washed ashore. The average amount of net loss per vessel per year in the mechanized sub sectors of deep-sea gillnet fishing is 589 kg, or 24.6 % and 36.2 % in motorized multi-day subsector of the total gear on board. (Thomas, 2020). ALDFG potentially pose safety risks for fishers if they get entangled with the active fishing gear that the fishers use and vessel propulsion systems (Kamei et al., 2014). It is estimated that ALDFG contributes 10% (by volume) in global marine litter and a global figure of 640 000 tonnes per year (Macfadyen et al., 2009). There fore the fishing gear must be operated cautiously to avoid gear loss either accidentally or intentionally. The Share of ALDFG varies across countries are Brazil (46%), Japan (11%) and US (7%). Approximately, the contribution of ALDFG is 6% of all fishing nets, 19% of all traps and pots, and 29% of all fishing lines are estimated to be lost around the world each year (Richardson et al., 2019). .

Gear marking is an effective method to enables the state to take effective action against defaulters in case of Abandoned, Lost and Discarded Fishing Gear (ALDFG). It is an important mechanism for regulating legal and illegal fisheries. If a gear is well marked and has sufficient identification and it can be linked to vessel or gear registers. The basic purpose of gear marking is to determine ownership and to trace back information regarding the gear (Edwin et al., 2020). In the gillnet sector of Veraval, numbering and special markings on thermocole floats attached to the head rope. In Cochin area, there was no marking system for gillnets. In Vishakhapatnam, float colour, shape and arrangement in head rope were used for differentiation. Special knotting on the head rope and float line is also practised, but no marking is seen on the webbing portion. Cement sinkers were marked by carving letters, symbols and numbers. The artisanal fishermen of Kerala operating small gillnets in back-waters use small plastic bottle/piece of polyurethane foam (PUF) sheet as identification marks.

Light fishing

Light fishing is a fishing aggregating method has been found to be environmental-unfriendly due to catching of immature stocks, overfishing, high rate of bycatch and discard and produce green gas emission (Solomon and Ahmed, 2016). The use of artificial light in fishing operation is attract and aggregate fish and eventually capture them using various fishing gears such as hooks, gill net, purse seine, beach seine, and cast net. The major groups of fishes which possess light attraction response are sardines, mackerel, anchovies, carangids and squids (Achari et al., 1998). Light fishing is mainly reported in India, Indonesia, Ghana and East Africa. Due to the introduction of the electric lamps such as incandescent, fluorescent and mercury lamps., the light fishing has been widely spread to the offshore fisheries to the large scale commercial level fisheries. Artificial light is harmful to female sea turtles when searching for a beach hatchery, which can produce unbalanced sex ratio of hatchlings and higher hatchling mortality. The use of artificial lights at night have been shown to increase mass collisions of seabirds, which contributes directly to mortality and the sustainability of seabird populations (Montevecchi, 2006).

In mechanized fishing operations, fishing with artificial light contributes to greenhouse gas emissions. Around 15% more Global Warming Potential (GWP) is estimated in purse seiners using light fishing compared to normal purse seiner (CIFT, 2021). The difference in super structure, extra power generation units for lights, onboard ice making etc. increases GWP. Another potential source of greenhouse gas is the production process that is needed for making fishing lights.

Chemicals and plastics often require significant energy sources in order to be manufactured. A single small low-powered LED light weighing 57.6 g will produce 345.6 g of CO2 to be manufactured (Khanh & Paul, 2019). There are some regulations in light fishing were made by different countries such as India, Thailand, Yemen, Ghana, China and Philippians. In India, prohibits the use or installation or operation of surface or submerged artificial lights/ LED lights, fish light attractors or any other light equipment with or without generator, on mechanized fishing vessel or motorized fishing craft, for trawling, purse seining or gillnetting operations in the Indian EEZ beyond territorial waters. In Thailand, fishing by all types of purse seine nets using light lures was prohibited off the coast of Trat province in the Gulf of Thailand, as they were found to predominantly attract small fish. In Ghana, the chief fishermen in three coastal districts of the Western region have banned light fishing to enable the fingerlings to have enough time to grow and hatch during the off-fishing season. Light fishing is banned from the boundary of Fujian province and Guangdong province of China. The number and candle light power or intensity of superlight and fishing light attractor used in commercial fishing vessels shall be regulated by the Department of Philippines and the use of superlight is banned within municipal waters and bays.

Increasing energy use in fishing

Modern fishing is one of the most energy intensive methods of food production. Fossil fuels used as a dominant energy source in operation of motorised and mechanised fishing vessels. It is a non-renewable resource which releases high amount of carbon dioxide and other greenhouse gases (GHGs) to the atmosphere (Das & Edwin, 2016). Due to the increased level of fuel consumption in fishing vessel operations, emission of GHGs also increased which finally led to climate change (Muir, 2015). Code of conduct for responsible fisheries (CCRF) of FAO highlights the need for efficient use of energy in the fisheries sector. The upper safety limit for atmospheric CO_2 is 350 parts per million (FAO, 1995). A fuel of 1378.8 million litres were consumed by annually and releases about 3.13 million tonnes of CO_2 into the atmosphere. The maximum GWP is contributed by trawler (96.3%), followed by the purse seiner (82.6%) and longliner (61.8%) for the time of fishing operation.

Trawling is an energy intensive fishing method, consumes 1.8 to 11 times more fuel when compared to gillnetting, longlining, ring seining and purse seining for every kilogram of fish produced (Gulbrandson, 1986; Aegisson & Endal, 1993; Boopendranath, 2000). Drag is the most important factor contributing to the fuel consumption and thereby energy efficiency and profitability of fishing operations. The drag of trawl gear components varies considerably according to the design and rigging and depending on the operating conditions. Drag of 18m semi pelagic trawl (HDPE) netting consumes 13779.27 kg fuel compared to the drag of 18m semi pelagic trawl netting (UHMWPE, large mesh) consumes 3713.78 kg fuel. Reduce the amount of netting surface area, knotless netting, large mesh netting and thinner twine are some measures used for reducing drag in trawl systems.

Low drag trawl is an optimized design of trawl net based on empirical calculations and use of Ultra High Molecular Weight Polyethylene (UHMWPE) twines for gear fabrication. ICAR- CIFT designed and fabricated low drag trawls for fish and shrimp of head rope length 24.47 m and 33.0 m respectively. The drag and fuel consumption of low drag trawls are 17% and 10% lower when compared to conventional HDPE trawls (Sayana et al., 2018).

Otter boards contributes about 25 % of the total drag of the trawl system and is responsible for about 16% of the total fuel consumption in trawling operations (Hameed & Boopendranath, 2000). Suberkrub board creates little or no turbulence, have very low drag, which makes this a superior spreading device. Analysis of national level survey results by CIFT showed that the trawls presently in use have drag which is not proportionate to the installed engine power.

For the construction of different type of fishing gears, a certain amount of CO_2 is emitted to atmosphere based on the type materials used for the fabrication of the gear. In trawl net construction, the HDPE contributes 43.8% GWP as higher percentage followed by steel (32.5%), polyethylene (12.6%) and polypropylene fiber (11.1%). In case of gillnet construction, polyamide is contributed by 96.79% GWP followed by Polyvinyl chloride (1.7%) and least contribution by polypropylene (1.5%). In longline construction, the polyamide contributes 94 % GWP as higher percentage followed by Ethylene vinyl acetate (4.63%) and steel (1.2 %). In purse seine fabrication, Polyamide webbing contribute 92.7% of GWP followed by lead (sinker) (5.13%) and 1.45% of GWP is contributed by Polypropylene.

Hull fouling with slime, weeds and barnacles and the propeller covered with marine growth will result in a considerable reduction in boat speed and an increase in fuel consumption. The increase in fuel consumption due to hull fouling can be 7% after only one month and 44% after half a year if antifouling paint is not used (Gulbrandsen, 2012). To save the fuel and decrease the CO_2 emission which is adversely affected to environment, reduce the service speed of fishing vessel, install advanced fish finding equipment, keep the hull free from fouling, use the efficient propeller and change over from a petrol outboard engine to a diesel engine.

Low energy fishing methods

Gillnets and longlines are low energy fishing gears which are extensively used in the traditional, motorized and mechanized sectors. Traps are low energy and eco-friendly harvest technology for the inland fisheries and traditional marine sector. capital investment of trap fishing is relatively low and show high degree of selectivity (Meenakumari, 2009). Barriers, Stow net, Scoop net, Scrape net, Trap net, Aerial trap, Basket trap, Tubular trap, Filter trap, Kalava trap and Lobster trap are coming in this category. Modern lobster traps developed by ICAR- CIFT, which is semi-cylindrical in shape with rectangular frame and semicircular ribs made of rod. Traditional lobster fishermen especially along the southwest coast of India was used this trap which is 2.5 times more efficient than traditional traps in term of catches and also, they last for about 3-4 fishing seasons.

Fish aggregating devices (FADs) are deployed to enhance biological productivity in coastal waters, rehabilitate and conserve the depleting stocks, reduce the scouting time and energy use during harvesting operations and to enhance the income and the standard of living of the fishermen. These make the fishing operations energy efficient and cost-effective, for the benefit of traditional fishermen operating low impact fishing gears such as gill nets and lines.

A 15.5 m multi-purpose deep sea fishing vessel Sagar Kripa with steel hull was designed and developed by ICAR – CIFT with energy saving up to 17%. Fuel efficient multi-purpose IRS class fishing vessel Sagar Harita designed by Fishing Technology Division of ICAR-CIFT and built by Goa Shipyard Limited (GSL) is the latest innovation by CIFT. An optimized hull design made of marine grade steel with a bulbous bow and the cabin and wheel house is made of FRP to reduce weight and to improve the carrying capacity and speed. A 600-watt solar power panel is designed and installed for emergency lighting and navigational aids to promote the utilization of renewable energy resource in the sector. Based on the successful sea trials of the vessel F. V. Sagar Harita and the positive feedback from the fishers and fishing vessel owners, the commercial version of a

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of Government of India. Hence ICAR-CIFT joined hands with the largest shipbuilder in the country M/s Cochin Shipyard Limited (CSL) for the design of 22.5 m long liner cum gillnetter and CSL constructed 16 vessels for Tamil Nadu. ICAR-CIFT provided consultancy to these shipyards for the design evaluation and stability testing the vessels constructed by them. Since the successful operation of the research and commercial vessels ICAR-CIFT has been overlooking construction of nearly 200 vessels all over the country.

The use of liquefied natural gas (LNG) as ship fuel has recently gained attention in Europe, but also in Asia and the USA. A marine LNG engine is a dual fuel engine that uses natural gas and bunker fuel to convert chemical energy in to mechanical energy. The natural gas is stored in liquid state (LNG) and the boil-off gas is routed to and burned in dual fuel engines. The use of LNG as ship fuel will reduce sulphur oxide (SOx) emissions by 90- 95%. A lower carbon content of LNG compared to traditional ship fuels enables a 20-25% reduction of carbon dioxide (CO2) emissions. LNG is expected to be less costly than marine gas oil (MGO) which will be required to be used within the Emission Control Areas (ECAs). ICAR-CIFT has already initiated research in this field along with Petronet Kochi LNG terminal (Baiju, 2019).

ICAR-CIFT developed two solar powered FRP boat in 2014 and 2019, which can be used in aqua farms for aqua cultural purposes and for gillnetting, line fishing, transportation and aqua tourism. The twin hull construction gives high stability during the fishing activities and the deck area is wider compared to a similar sized conventional boat. The first vessel 3.63 m Loa FRP solar boat can run in the tribal fishers at Malampuzha reservoir and the second boat 8.0 m Loa solar boat is in use at Fish farm, MATSYAFED, Njarakkal (Baiju, 2019). The solar powerd boat does not burn fuel and not create atmospheric and sound pollution.

Issues related to synthetic webbing materials

Synthetic fibres are the major materials used for gear fabrication. It has greatly extended the endurance of fishing gears, and together with mechanized vessels, have increased the size and complexity of nets. Synthetic fibres are produced entirely by chemical process or synthesis from simple basic substances such as phenol, benzene, acetylene etc. Polyamide is a synthetic fibre, popularly known as nylon. Since the introduction of synthetic webbings in fishing, Polyamide (PA) multifilament were used for the fabrication of gill nets. PA multifilament is the first synthetic material to become popular in India replacing hemp and cotton. The material used for drift gill nets for large pelagics, viz. seer, tuna and shark also has been replaced by PA multifilament. Also, it is used for fabrication of purse seine and ring seine. Recently in many states of India, PA monofilament is replacing PA multifilament, used for the fabrication of gillnet and longline

(Thomas & Hridayanathan, 2002). Among the gear webbing materials, polyamide webbing contributes 77.94% CO_2 emission to environment (Das & Edwin, 2016).

Ultra-high molecular weight polyethylene (UHMWPE) is a type of polyolefin synthesized from monomer of ethylene. The most important property of UHMWPE fibre is the requirement of a thinner material compared to PA and HDPE, thus developing less drag resulting in fuel efficiency. Due to the light weight property with minimum drag in the water, the material helps fishers to reduce fuel costs by 40%. The trawls incorporating UHMWPE products showed excellent geometric characteristics and a considerably reduced hydrodynamic drag (Sendlak, 2001). In purse seines, the use of UHMWPE facilitates faster sinking due to better filtering and reduced drag. Faster sinking reduces the chances of escape of the fish shoal.

Sapphire PE netting manufactured from specialized polymers available in twisted and braided form is suitable for trawl nets and for cage culture. It has the highest knot breaking strength, knot stability and dimensional uniformity. Braided twine having compact construction restricts mud penetration and provides lesser drag. Sapphire ultracore is a knotless HDPE star netting with an outer layer of heavier sapphire ultracore which features strands of marine grade stainless steel as an integral part of the netting twine. The stiffness and cut resistance enable it to be used as a predator protection net cum cage bag net where the predation problem is very high.

Alternate materials for traditional fishing vessels

The major materials are used for the construction of fishing vessels include wood, fibre reinforced plastic, marine plywood, aluminium and steel. Wood has been used for the boat building sector for ages due to its excellent properties like buoyancy, workability, strength, elasticity, durability, heaviness (480-624 kg m-3 at 12% moisture content), load-bearing capacity, treatability, nail holding power, strength to weight ratio and poor transmission of heat (Lekshmi & Edwin, 2019).The positive environmental impact of a wood, it is a renewable resource, a low energy material and has a negative net carbon footprint (Table. 1) (Bose & Vijith, 2012). The wood is susceptible to deterioration by various biotic and abiotic agents. Chemical preservatives are used to protect the wood against the attack of fungi, insects and marine borers. At the same time, care has to be taken to prevent the leaching of metals from the chemical preservative treated wood which may pollute the marine eco-system (Edwin and Sreeja, 2011). The wood contributes Global

Warming Potential as negative value (-64.52%) compared to other boat building materials (Das &Edwin, 2016).

Table 1. Net carbon emissions in producing 1 tonne of material

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

(Source: Bose & Vijith, 2012)

Deforestation can result due to the deliberate removal of forest cover for agriculture, urban development sector or it can be an unintentional consequence of uncontrolled grazing and fires. The large quantity of wood used by the fishing industry also adds to deforestation. The utilization of coconut wood and rubber wood as an alternative material for marine purpose, reduces deforestation and it helps in maintaining the ecological stability and conserving the deteriorating environment. ICAR-CIFT has developed canoes using alternate materials like rubber wood and coconut wood for artisanal fisheries sector.

A simple technology has been popularized for development of traditional fishing canoe from rubber wood, which comes as a waste from rubber plantations. Though rubber wood is comparable to many structural timbers in terms of mechanical properties and working qualities, it is highly perishable under marine conditions. The study conducted by ICAR-CIFT proved that the rubber wood is suitable for construction of canoe after upgrading by chemical preservative treatment. Rubber wood can be made durable by treated with chemical preservatives after sheathing it with fibre glass- reinforced plastic. FRP sheathing in the rubber wood canoe provides water proofing, resistance to impact and abrasion and prevents leaching of wood preservative. It also helps to prevent attack of marine woodborers and other decay caused by bacteria and fungi results in less maintenance cost. The important dimensions of the two canoes, one for backwater fishing (6.05 m L_{OA}, 0.77 m breadth and 0.39 m depth) and 6.4 m L_{OA}, 0.83 m breadth and 0.42 m depth rubber wood canoe was used for marine fishing (Edwin, 2003).

Coconut wood is an alternate boat building material that has been zeroed in considering its availability, especially in coastal states and islands of India. ICAR-CIFT has designed and developed a traditional fishing canoe from the coconut wood, which can be used for artisanal fishing like ring seining, gillnetting etc. The preservative treatment on the coconut wood panels were standardized to enhance the physical and mechanical properties. The preservative treatment increases the durability of wood, prevents bio-deterioration and reduces the cost by 35-40%. After standardizing the treatment parameters for increasing the durability of the wood, a canoe of dimension 9.0 m L_{OA}, 1.50 m breadth and 0.70m depth was constructed. The coconut wood canoe is also cheaper when compared to the cost of preferred aini wood canoe.

Fibre reinforced plastics or FRP is used as boat building material due to its low production cost, easiness of fabrication and anticorrosive property. It is also easy and simple to fabricate. The main material components of FRP material are the reinforcing agents like glass fibre in the form of thin fibre and a plastic resin capable of impregnating fibres. For the construction of FRP boat, the primary requirement is a mould. The most popular reinforcement used is a form of glass processed into filaments which are then chopped and supplied in rolls. The thickness depends on the weight of the glass in grams per square meter. The two main types of glass fibres like chopped strand mat and woven rovings and resin are mainly used in FRP vessel construction. The chopped strand mat (CSM) is made up of long fibre glass strands that are randomly oriented and held together with a binder glue. These are available in fabric form as rolls or in small folded packages with varying thickness. Twenty years is often quoted as the lifespan of an FRP vessel. However, there are many vessels are still operating in inland and marine fisheries sector. In coming years more and more boats are going to end of its life and fishers have a tendency to burn these boats. But burning of FRP boats in the beaches leads to emissions of many greenhouse gases (GHG) to the atmosphere. FRP material contributes 75.65% of Global Warming Potential (GWP) for the time of vessel construction. In FRP sheathed wooden fishing vessels, CO2 equivalent was primarily contributed by FRP sheath (41.3%) followed by bronze (23.7%) and copper nail (19.6%).

Marine plywood is extensively used for marine vessels construction due to its commercial feasibility, high economic viability and relatively low damage in aquatic conditions. It is prepared by gluing together a number of thin veneers of wood using a waterproof adhesive such as epoxy or phenol resorcinol. The wooden ply-woods are bonded under high temperature and pressure with phenolic resin glue. Best quality marine grade plywood should have at least 5 layers of veneers.

Many uses of plywood in boats involve laminating fiberglass over a plywood boat component. The fiber glass coating protects the underlying plywood from abrasion and wear during landing and launching of boats. Marine plywood boats can ensure protection in severe conditions if it is made of durable or treated veneers. The life of a marine plywood boat is 5-7 years. The end life of disposal of FRP sheathed marine plywood boats is a common phenomenon in tropical developing countries. This adds to the marine debris and later if not properly recycled can turn to micro plastics and enters to the food chain.

Aluminium is selected as a boat building material due to its lightweight with high strength, durability and easiness to repair. Since it is lightweight, it has more carrying capacity and greater speed. The use of aluminium for fishing craft construction offers a number of advantages that includes improved stability, reduced displacement and therefore improved maneuverability and increased cargo carrying capacity, increased speed and increasing operating range, decreased engine size, decreased fuel consumption, reduced maintenance therefore less idle time. A 5.22 m L_{OA} aluminum alloy boat was designed and constructed by ICAR -CIFT for fishing and related activities in reservoirs and rivers. This material avoids expenditure on paints etc. and gives good re-sale value.

Steel has good strength, elasticity and durability and it is mainly used to construct hulls of large vessels mainly beyond 50 m in length. Mild steel is commonly used to construct fishing vessels where the carbon content is 0.15 to 0.30%. Steel vessels have good strength, elasticity and durability. Steel can be easily bent and twisted so that larger designs/sections can be fabricated easily with less wastage. The specific gravity of steel is 7.84 where the weight is comparatively more than wood, aluminium and FRP vessels. Steel is prone to corrosion and anticorrosive paints are essential for the hull protection. Steel material produces 82. 8% of Global Warming Potential (GWP) for the time of vessel construction. In steel vessels, CO_2 equivalent was contributed maximum by steel plates (65.8%) followed by bronze (24.1%) and welding arc (4.6%) (Jha et al., 2021).

Marine plastic pollution

Micro-plastics in seawater and marine sediments are rapidly increasing, and are entering into the food chain becoming a long-term threat to the mankind. Over 300 million tons of plastic are produced every year for use in a wide variety of applications. At least 8 million tons of plastic end up in our oceans every year, and make up 80% of all marine debris from surface waters to deep-sea sediments. Marine species ingest or are entangled by plastic debris, which causes severe injuries and deaths. Plastic pollution threatens food safety and quality, human health, coastal tourism, and contributes to climate change.

Advanced Technologies in fisheries sector

Potential Fishing Zone (PFZ) is a reliable and short-term forecast on the fish. This is the first advisory service started by INCOIS. This service was started by the Ministry of Earth Sciences with the help of the Department of space and several institutions under the Ministry of Agriculture. These organizations are collaborating with the State Governments of the beneficiary states to offer these services to the end users. The backbone of this service is the real-time data for ocean color and SST(sea surface temperature) provided by the OCEANSAT and NOAA (National Oceanic and Atmospheric Administration) respectively. Features such as oceanic fronts, meandering patterns, eddies, rings, Upwelling areas etc. are identified sites for fish accumulation. These features can easily be identified from Sea Surface Temperature and Chlorophyll data. The validation of PFZ helps in finding fish schools and productive fishing areas that can minimize the fuel consumption and time expended in commercial fisheries. Another feature of PFZ service is the generation of species-specific advisory to enable the fisher folk to distinguish between the exploited and under-exploited species in the potential fishing zones. This enables them to have sustainable fishery management by targeting only the under-exploited species in the fishing zones. This approach enables them to avoid fishing the over-exploited species over and over again. One such species-specific advisory is Tuna Fisheries Forecasting System that enables the fishing community to adequately prepare for the Tuna catch (Kamai et al., 2014).

Technological and digital advances would allow innovative monitoring equipment to be attached to traditional sampling gear and collect more data such as ecosystem in formation, in order to better manage fish stocks and tackle IUU fishing. For instance, visual inspections in complex habitats using imaging systems installed on robotic and autonomous underwater vehicles (AUVs) can contribute to the advancement of marine science and better knowledge of fish stocks. Collaborative monitoring, control and surveillance (MCS) tools depend on the willingness of a captain of vessel; non-collaborative tools rely on the decisions taken by the authorities in control (on when and where the vessel is monitored).

Collaborative tools include Vessel Monitoring System (VMS) and Automatic Identification System (AIS). Non-collaborative tools include optical or radar satellites. New data processing technologies in fisheries includes big data, block chain, smart weighing at sea, Radio-frequency identification (RFID), smart phones for monitoring, artificial intelligence, drones, and on-board cameras (Girard & Payrat, 2017).

Vessel Monitoring System (VMS) was originally a satellite-based system that provided data on the time-stamped location, course and speed of vessels to fisheries authorities at regular intervals.VMS are implemented nearly worldwide with various ranges of transceivers. Some countries (e.g., Algeria) only equipped tuna-seiner vessels or specific vessels for fishing in the high seas in order to comply with recommendations by Regional Fisheries Management Organizations (RFMO).

Automatic Identification System (AIS) is a ship-reporting system based on messages broadcasted by vessels carrying transponders. It was developed primarily as a tool for maritime safety to avoid vessel collision by Vessel Traffic Services (VTS) and as a means for coastal states to receive information on vessels operating near their coasts. AIS transponders send and receive signals, using a very high-frequency (VHF) transmitter, broadcast to receiver devices on other ships or to land-based systems. By sending and receiving regular communications about their identity and course, vessels can avoid collisions and navigate safely in low visibility.

Electronic Recording and Reporting System (ERS) is commonly referred to as E-Logbook, in comparison with former paper-based logbooks. E-logbook data (logs records) contribute to better management of fish stocks by keeping track of catches (origin and volume) and gearused.ERS collects information on species, volume and areas of catches, important data for fisheries. On-board logbooks are mandatory requirements for high sea fishing vessels in some RFMOs such as the Indian Ocean Tuna Commission.

Facing tremendous increase of data for fisheries monitoring, control and surveillance, the Big Data can help in sorting out data coming from new technological tools. It offers an alternative to traditional database and requests tools. Large fishing vessels currently use motion-compensated weighing system at sea in order to directly measure and store raw weight of the catch. The movement of vessel at sea does not allow determining the exact weight of the catch. Thus, the smart weighing system at sea calculates the weight of catches while taking into account movement of vessel. Data is then regularly sent to fish market and ports by satellite support to update landing forecast.

Drones (fully or partly unmanned vehicles) is one of the prominent fields of application of new technology for sustainable fisheries. Three main types of drones may be distinguished are UAV (Unmanned Aerial Vehicle), USV (Unmanned Surface Vehicle) and UUV (Unmanned Underwater Vehicle). Drones can be used for fish stock assessments and monitoring and controlling of MPAs (Marine protected areas). Electronic Monitoring loosely consists of a closed video or photographic system, integrated with a sensor system that can be used to view changes in fishing activity and to trigger or coordinate detailed viewing. The camera and sensor systems do not allow external or manual inputs or manipulation of data. On-board survey cameras may identify interactions with bycatch species and are especially useful when recording bycatches of protected species. The viewed data can also provide a secondary source of data, for example, to validate catch and bycatch log sheets (Girard & Payrat, 2017).

Tiny microprocessors and sophisticated remote sensing systems is possible to explore the lives of marine animals and the open ocean from the perspective of individuals equipped with smart tags. Satellite tags provide researchers with information about migratory routes and internal physiological processes such as digestion. smart tags are especially useful in tracking highly migratory species like sharks, tuna, and albacore, Sea turtles, Sea lions, seals and Whales. Underwater vehicles are used to study life in the ocean, including autonomous underwater vehicles (AUVs), manned submersibles, and remotely operated vehicles (ROVs). ROVs are tethered to a surface vessel, whereas AUVs operate independently. AUVs receive commands from an operator-controlled computer as to where, when, and what they sample. They also carry equipment for sampling and surveying such as cameras, sonar, and depth sensors.

Developments in acoustic fish detection satellite-based remote sensing techniques and the overall awareness of the need for responsible fishing to ensure long-term sustainability of the resources, protection of the biodiversity, environmental safety and energy efficiency. The most well-known and widely used acoustic instruments for fish detection are echo sounder and sonar. Echo sounders are used for depth recording for navigation purposes and position fixing, ground or sea bed discrimination, determination of sea bed contour, location of wrecks and hazardous areas, and location of fish and determination of its depth of occurrence. Sonar is an indispensable tool aimed trawling and purse seining.

Conclusion

Fisheries should be managed to ensure that fishing are conducted in ways that minimize negative impacts on the environment. Encourage diversification of excess capacity into low energy fishing methods. Future of sustainable fisheries depend on less fishing effort, lower exploitation rates, larger fish stocks, gradual reduction of bycatch, concern about the ecosystem impacts of exploitation and elimination of destructive fishing practices. The diversity of different fishing gears and crafts and its intensity and efficiency of fishing operations have increased significantly during the recent decades in India. Different type of fishing operation has created a significant negative impact on ecosystem. The minimization of the environmental impacts on fishing, ICAR-CIFT developed a vast number of technologies for sustainable fishing and fisheries conservation.

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An introduction to seafood processing

Ashok Kumar K.
Principal scientist
Fishing Processing Division, ICAR- CIFT, Cochin

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 helps 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 controling pathogenic microorganisms
- Modern food processing also improves the quality of living by way of healthy foods developed for special people who are allergic to certain ingredients, diabetic etc 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 fetches maximum price compared to all the other forms of value added products as it maintains the freshness. The candidate species for live transportation include high value species, cultured grouper, red snapper, seabreams, seabass, red tilapia, reef fish, air breathing fishes, shrimp, crabs, lobster, clams, oyster and mussels. These are normally transported in air cargo maintained at low temperature in order to lessen the metabolic activities of the animals.

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).

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 minimise the oxidative deteriorative reactions and aerobic bacterial growth. Vacuum packaging can considerably extend the viable shelf life of many cooked foods. The use of vacuum packaging, in gas impermeable and heat stable materials, has many advantages, which include; no or low risks of post pasteurisation contamination, ease of handling, Inhibition of growth of aerobic spoilage organisms and inhibition or slowing of deleterious oxidative reactions in the food during storage due to oxygen barrier properties of the packaging material.

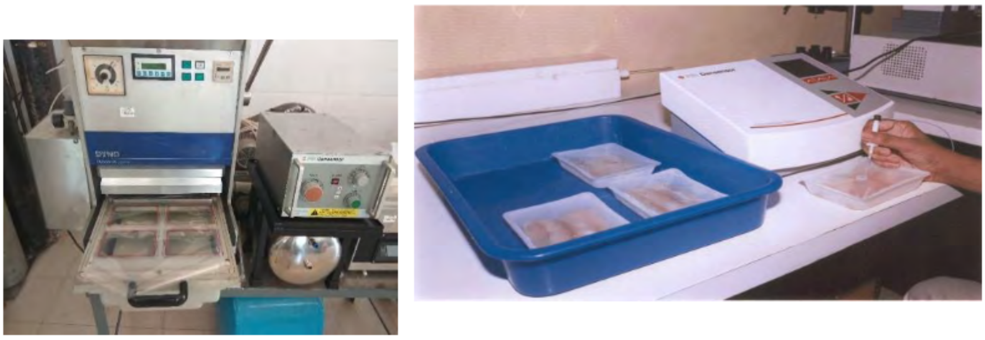
There are number of criteria required for the films used for vacuum packaging in large scale production methods. These requirements include: high durability, ie. ability to withstand considerable mechanical stresses during packaging, handling and transport, retention of flexibility even at low temperatures (-2 to 4°C) to enable satisfactory handling in the packaging and refrigeration rooms, ability to withstand heating to at least 150°C without structural damage, leaching of potentially toxic plastics or plasticisers, impermeability to liquids, including oils and fats and macromolecules, impermeability to gases, in particular oxygen, so that oxidative deterioration of the packaged food stuffs is limited or inhibited, manufactured from non-toxic, food acceptable, odourless materials and must be able to create airtight durable heat seals to close packs. Many of these criteria have been met by a range of materials mostly 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 analyser

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.

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

Smoked Fishery Products

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

Hot and liquid smoked fish chunks and masmin chunks

Retort pouch processing:

As in canning, retort pouch food is sterilized after packing, but the sterilizing procedure differs. The pouches are processed in an over pressure retort. The time and temperature will be standardized depending on the product. With the availability of retort pouches it can function as an excellent import substitute for metallic cans. Besides, cost reduction retort pouch packages have unique advantages like boil in bag facility, ease of opening, reduced weight and do not require refrigeration for storage. Processed food products can be kept for long periods at ambient temperature. The energy saving is more in processing in flexible pouches compared to cans. On a comparison of total costs, including energy, warehousing and shipping, the pouch looks even more 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 shelflife. 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 fi incident on the water molecules, the permanently polarized dipolar molecules try to realign in the q fi , 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-fl fi 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.

Infrared and Radiofrequency Processing Technologies:

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

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

High pressure processing:

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

Ultrasound Processing:

Ultrasound refers to sound that is just above the range of human hearing, i.e. above frequency of 20 MHz. Ultrasound when propagated through a biological structure induces compressions and depressions of the medium particles imparting a high amount of energy to the material. The sound ranges for food applications employed can be divided into two, namely, low energy, high frequency diagnostic ultrasound and high energy low frequency power ultrasound. Low energy applications involve the use of ultrasound in the frequency range of 5-10 MHz at intensities below 1 W/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^{0}C). De-skinning of tuna, Herrin, Squid were also carried out by using different enzyme technology.

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Processing and Value Addition in Seafood Sector

George Ninan
Principal scientist
Engineering Division, ICAR- CIFT, Cochin
george66jiji@gmail.com

Fish is one of the healthiest foods available to man and there is an ever-increasing demand for fish and fishery products. 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.

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 values added and diversified products both for export and internal market based on fish, shrimp, lobster, squid, cuttlefish, bivalves etc. have been identified. This paper gives an overview of the processing techniques, emerging technologies and the value-added products from fish and shell fish.

Chilling

Chilling is an effective way of reducing spoilage by cooling the fish as quickly as possible without freezing. Immediate chilling of fish ensures high quality products (Connell, 1995: Huss, 1995). Chilling by use of ice is the most important method employed commercially. The storage life of fish kept in ice depends on a number of factors which include species, size, method of capture, fat content, breeding conditions, feeding regime and the method of killing. In general, the keeping quality of non-fatty fish is better than fatty fish in ice storage. The quality and quantity of ice used are important factors in determining the shelf life of iced fish. In tropical countries, a 1:1 fish to ice ratio is ideal for ice storage. It is recommended to add about 12-20% extra ice to the fish in order to compensate for water loss from melting and bad handling (Zugarramurdi *et al*., 1995). It is generally accepted that some tropical fish species can keep for longer periods in comparison to fish from temperate or colder waters. Up to 35% yield of high value products can be expected from fish processed within 5 days of storage in ice, after which a progressive decrease in the utility was observed with increase in storage days (Venugopal and Shahidi, 1998).

Transportation of Chilled Fish

Land transportation of chilled fish is carried out in insulated or mechanically refrigerated vehicles. The refrigerated vehicle used for chilled fish transportation should have a minimum inside temperature of 7 ^{0}C (Venugopal, 2006). Air shipment of chilled fish requires a lightweight and protective container. Pads of nonwoven fabric encapsulating synthetic absorbent powder are used for chilling of air shipped fish. Special thermal barrier films are used in combination with the pads to protect fish containers from heat (Subasinghe, 1996).

Transportation of live fish and shellfish

Transportation of fish, crustaceans and molluscs in live condition is the best method to ensure that the consumer is supplied with fresh product. In India, traditional mode of live transport in open earthen containers and metal containers was practiced (Jhingran, 1975). In terms of the range of species and the distance shipped, tropical fishes stand first in live fish transport. Waterless transportation of live fish is also practised for many species where the animals are kept in moist conditions under optimal cold temperatures.

Freezing

Freezing is one of the better methods to preserve fresh fish. It may be either slow freezing or quick freezing. Slow freezing is accomplished by placing the product at a low temperature and allowing it to freeze slowly usually in still air. Quick freezing is accomplished in any one or combination of the following four methods:

Immersion freezing

Indirect contact freezing

Air blast freezing and

Cryogenic freezing

Air freezing

Sharp freezing

Packaged or unpackaged marine products can be frozen in air at temperature from -18 to -40°C. If "sharp" freezing is employed, air is circulated slowly or not at all and the rate of freezing is very slow. It ranges from 3-72 hour or more depending on the conditions and size of the product. Sharp freezing is not common in modern freezing operations.

Air blast freezing

Circulating cold air at high speed enables freezing to proceed at a moderately rapid rate and this method is referred to as air-blast freezing. Air-blast freezing is usually accomplished by placing the products on a mesh belt and passing it slowly through an insulated tunnel containing air at-18 to -34°C or lower, moving counter current to the product at a speed of I to 20 meter/sec. Air at -29°C and at a speed of 10-12 meter/sec, is often satisfactory, although lower temperatures are preferred. Air blast freezing is economical and is capable of accommodating products of different sizes and shapes. It can result in (1) excessive dehydration of unpackaged products if conditions are not carefully controlled, and this in turn necessitates frequent defrosting of equipment and (2) undesirable bulging of packaged products which are not confined between flat rigid plates during freezing.

Spiral Belt Freezer

Modern designs of belt freezers are mostly based in the spiral belt freezer concept. In these freezers a conveyor belt that can be bent laterally is used. The present design consists of a self-staking and self-enclosing belt for compactness and improved air flow control. The number of tiers in the belt stack can be varied to accommodate different capacities and line layouts. The belt is continuous. The products are placed on the belt outside the freezer where it can be supervised. As the belt is continuous it is easy for proper cleaning. Both unpacked and packed products are frozen and the freezer gives a large flexibility both with regard to product and freezing time. Both horizontal and vertical air flow can be used. Vertical airflow is more efficient.

Carton freezer

This freezer consists of a number of carrier shelves which are automatically moved through the section of the unit. The operations are carried out hydraulic power with mechanical linkage to coordinate different movements. The boxes are fed automatically into the freezer on a feeding conveyor.

Fluidized Bed Freezing

Marine products of small size like prawns can be fluidized by forming a bed of prawns on a mesh belt and then forcing air upward through the bed at a rate sufficient to partially lift or suspend the particles. If the air used for fluidization is sufficiently cooled, freezing can be achieved at a rapid rate. An air velocity of at least 2 meter/sec. or more is necessary to fluidize the particles and an air temperature of - 35°C is common. The bed depth depends on ease of fluidization and this in turn depends on size, shape and uniformity of the particles. A bed depth of slightly more than 3 cm is suitable for small prawns where as a depth of 20 to 25 cm can be used for non-fluidizable products such as fillets. Fluidized bed freezing has proven successful for many kinds and sizes of products. The best results are obtained with products that are relatively small and uniform in size. Some fluidized-bed freezers involve a two stage freezing technique wherein the first stage consists of an ordinary air-blast freezing to set the surface of the product and the second stage consists of fluidized bed freezing.

The advantages of fluidized bed freezing are (1) more efficient heat transfer and more rapid rates of freezing and (2) less product dehydration and less frequent defrosting of the equipment. Dehydration loses of about 1% have been reported during fluidized bed freezing of prawns. The short freezing time is apparently responsible for the small loss of moisture. The major disadvantage of fluidized-bed freezing is that large or non-uniform products cannot be fluidized at reasonable air velocities.

Contact Plate Freezing

Fish products can be frozen by placing them in contact with a metal surface cooled by expanding refrigerants. Double contact plate freezers are commonly used for freezing fish/prawn blocks. This equipment consists of a stack of horizontal cold plates with intervening spaces to accommodate single layers of packaged product. The filled unit appears like a multi layered sandwich containing cold plates and products in alternating layers. When closed, the plates make firm contact with the two major surfaces of the packages, thereby facilitating heat transfer and assuring that the major surfaces of the packages do not bulge during freezing. Vertical plate freezers are also in use especially onboard fishing vessels. Contact plate freezing is an economical method that minimises problems of product dehydration, defrosting of equipment and package bulging. In this method the packages must be of uniform thickness. A packaged product of 3 to 4 cm thickness can be frozen in I to 1.5 hour when cooled by plates at -35°C. Freezing times are extended considerably when the package contains a significant volume of void spaces.

Liquid Immersion Freezing

Liquid immersion freezing or direct immersion freezing is accomplished when a product is frozen by immersing or by spraying with a freezant that remains liquid throughout the process. This technique is occasionally used for fish and prawns. Liquid immersion freezing can result in moderately rapid freezing. Freezants used for liquid immersion freezing should be non-toxic, inexpensive, stable, reasonably inert, and should have a low viscosity, low vapour pressure and freezing point and reasonably high values for thermal conductivity. Freezants should have a low tendency to penetrate the product, little or no undesirable effects on organoleptic properties and require little effort to maintain desired standards for sanitation and composition. Aqueous solutions of propylene glycol, glycerol, sodium chloride, calcium chloride and mixtures of sugars and salt have been used as freezant.

Cryogenic Freezing

Cryogenic freezing refers to very rapid freezing by exposing food products to an extremely cold freezant undergoing change of state. The fact that heat removal is accomplished during a change of state by the freezant is used to distinguish cryogenic freezing from liquid immersion freezing. The most common food grade cryogenic freezants are boiling nitrogen and boiling or subliming carbon dioxide. Boiling nitrous oxide also has been considered, but at present it is not being used commercially. The rate of freezing obtained with cryogenic methods is much greater than that obtained with conventional air-blast freezing or plate freezing, but is only moderately greater than that obtained with fluidized bed or liquid immersion freezing. For example, shrimp freeze in about 9 min in a commercial liquid nitrogen freezer and in about 12 min in a fluidized bed freezer. Currently liquid nitrogen is used in most of the cryogenic food freezers. Usually liquid nitrogen is sprayed or dribbled on the product or alternatively very cold gaseous nitrogen is brought into contact with the product. Freezing with carbon dioxide usually involves tumbling the product in the presence of powdered or liquid carbon dioxide. Carbon dioxide is absorbed or entrained by the product in this method. This entrapped CO_2 should be removed before it is packaged in an impervious material.

Crusto Freezer

This is a combination of cryogenic freezing system and air blast freezing system. The equipment utilizes the possibility of a fast and efficient crust freezing of extremely wet, sticky products which can then be easily handled in a spiral belt freezer or a fluidized bed freezer without deformation or breakage.

Pre-freezing and Freezing Consideration

The quality of frozen-thawed cooked fish is influenced by a number of factors including species, composition, size, how and where caught, elapsed time between harvest and freezing, the state of rigor and quality when frozen and the details of freezing process and frozen storage.

The major problems encountered during the freeze-processing of fish are oxidative deterioration, dehydration, toughening, loss of juiciness, and excessive drip. Effective pre freezing and freezing techniques are available for controlling many of these problems except toughening and loss of juiciness. Reasonable control of toughening and loss of juiciness can be accomplished only by storing fish for a minimal time and / or at temperatures at -18°C or lower. Undesirable oxidative changes in fish can be minimized by (1) eliminating oxygen (2) avoiding contamination with heavy metals (oxidative catalysts) (3) adding antioxidants and (4) by using low storage temperature. Dehydration can be avoided by applying glaze and suitable protective coatings.

Individually Quick-Frozen Products (IQF)

Lobster, squid, cuttlefish, different varieties of finfish etc. are processed in the individually quick-frozen style. IQF products fetch better price than conventional block frozen products. However, for the production of IQF products raw-materials of very high quality need to be used, as also the processing has to be carried out under strict hygienic conditions. The products have to be packed in attractive moisture-proof containers and stored at –30°C or below without fluctuation in storage temperature. Thermoform moulded trays have become accepted containers for IQF products in western countries. Utmost care is needed during the transportation of IQF products, as rise in temperature may cause surface melting of the individual pieces causing them to stick together forming lumps. Desiccation leading to weight loss and surface dehydration is other serious problem met with during storage of IQF products.

Some of the IQF products in demand are prawn in different forms such as whole, peeled and de-veined, cooked, headless shell-on, butterfly fan tail and round tail-on, whole cooked lobster, lobster tails, lobster meat, cuttlefish fillets, squid tubes, squid rings, boiled clam meat and skinless and boneless fillets of white lean fish. IQF products can be easily marketed as consumer packs, which is not possible with block frozen products. This is a distinct advantage in marketing.

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 (Mallick *et al.,* 2006; Sreenath *et al.,* 2007)

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

Curing

The traditional methods of processing fish by salting, drying, smoking and pickling are collectively known as curing. Cured fish consumption is more in areas where the availability of fresh fish is comparatively limited, namely interior markets and hilly areas. This is also the cheapest method of preservation, since no expensive technology is used. In India roughly 20 % of the fish caught is preserved by curing. Considerable quantities of cured fish are also exported, mainly to Singapore, Sri Lanka and to the Middle East. Simple sun drying was the widely practised traditional method of fish preservation. By this, preservation was achieved by lowering of water content in the fish, thereby retarding the activity of bacteria and fungi. The heat was able to destroy the bacteria to a certain extent. Later on, a combination of salting and drying or salting, smoking and then drying were developed.

Methods of Drying

There are basically two methods of drying fish. The common one is by utilizing the atmospheric conditions like temperature, humidity and airflow. This is traditional sun drying. The other is dehydration or artificial drying, by using artificial means like mechanical driers for removal of moisture from the fish under controlled conditions.

Sun drying depends heavily on the natural weather conditions since the fish is dried by heat from the sun and the air current carries the water away. Here there is no control over the operations and many a time the losses cannot be substantiated. Hence it is necessary that the operations be controlled to get a product, which has an extended shelf life, but at the same time the texture, taste and flavour is maintained. It is here that artificial driers where processing parameters are controlled gain a lot of importance. Such processes are carried out in a controlled chamber or area. Such products have advantages over sun-dried products since they have better keeping quality and longer shelf life.

In mechanical driers, removal of water from the fish is achieved by an external input of thermal energy. This is an expensive method since there is need for fuel for heating and maintenance of the temperature. The drying chamber consists of a long tunnel in which the washed and cleaned fish is placed on trays or racks. A blast of hot air is passed over the material to be dried. After the required degree of drying the product is removed from drier and packed.

Salting

This is one of the oldest methods of preservation of fish. Salting is usually done as such or in combination with drying or as a pretreatment to smoking. During salting osmotic transfer of water out of the fish and salt into the fish takes place, which effect fish preservation. It is based on different factors like diffusion and biochemical changes in various constituents of the fish. Salting amounts to a process of salt penetration into the fish flesh. Penetration ends when the salt concentration of the fish equals that of the surrounding medium. Loss of water during salting limits bacterial growth and enzyme activity, thus preserving the fish. The high salt content prevents the growth of normal spoilage microflora in the fish; but halophiles, which can survive 12-15% of salt, will survive.

Smoking

Smoke curing is another traditional method of preservation of fish. It is generally a combination of salting, smoking and drying. Smoking is usually done in a specially designed kiln or a room. The source of smoke is wood, sawdust or coconut husk, depending on the particular flavour required. The fish that is salted and partially dried is used for smoking. Smoking can be done at temperatures below 35 ^{0} C (cold smoking) or at higher temperature (hot smoking). Liquid smoking by immersion in smoke liquor and electrostatic smoking is also practised in different countries.

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.

Irradiation

Irradiation treatment involves controlled exposure of the food to radiation sources such as isotopes of cobalt (^{60}Co) or cesium (^{137}Cs), which emit gamma rays, and also X-rays and electron beams (Lagunas-Solar, 1995). Radiation processes that can be applied to fishery products include radurization (pasteurization of chilled fish), radicidation (sanitization of fresh and frozen products including fish mince by elimination of non-spore forming pathogenic bacteria) and disinfestation.

Radurization of fresh fish at 1 to 3 kGy reduces initial microbial loads by 1 to 3 log cycle, essentially reducing spoilage causing bacteria and extends their chilled storage life 2-3-fold. The treatment is effective for the extension of shelf life of most of the marine and freshwater fish species. Radicidation is sanitation of frozen products including fish minces by elimination of non-spore forming pathogenic bacteria such as Salmonella, Vibrio and other species at a dose of 4 to 6 kGy. The treatment, however, is limited in its ability to eliminate viruses and *Clostridium botulinum* type E spores, which jeopardize the safety of seafood through production of lethal botulinum toxin. Several studies have established the feasibility of low dose gamma irradiation at a dose of 1kGy for the disinfestations of dried fish. Irradiation at doses in the range of 0.1 to 1.0 kGy can prevent development of beetle larvae and adults in packaged, salted, dried fishery products (Rodrick, 1999; Venugopal 1990; Venugopal and Shahidi,1998; Venugopal *et al.,* 1999).

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 ‘ ’ , 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 coat ‘ ; ‘ ’ 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 involve fully automated batter and breading lines which start from portioning and end with appropriate packaging of the product (Suderman & Cunningham, 1983; Dikhoof, 1990; Hutchison *et al.,* 1992; Joseph, 2003). 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 (Babitt, 1986). Also, low bone content in the mince (01-0.4%) is desirable for better functional and sensory properties (Grantham, 1981). Depending on the type of raw material, fish mince can have a frozen storage life up to 6 months without any appreciable quality deterioration (Ciarlo *et. al.,* 1985). 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. Lipid oxidation and protein denaturation during frozen storage of mince can be prevented by the incorporation of spices, cryoprotectants and hydrocolloids (Joseph, *et.al.,* 1992; Jiang, *et. al*.,1986)

Fish mince is a major source of raw material for the preparation traditional products such as patties, balls, wafers, loaves, burgers, fish fingers, dehydrated fish minces, cutlets and pickled products (Regenstein,2004; Grantham,1981; Venugopal and Shahidi, 1995; Venugopal, et*. al.*,1992; Joseph, *et.al*., 1984). The mince from different species could be combined to prepare composite fillets (Venugopal, 2006).

Surimi

Surimi is stabilized myofibrillar protein obtained from mechanically deboned flesh that is washed with water and blended with cryoprotectants (Park, 2005). 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.

Fibreized products

Fibreized 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 (Hassan & Mathew, 1999). Sausages prepared from rohu mince treated with potassium sorbate had a shelf life of 16 days at refrigerated temperatures (Sini *et. al*., 2008).

Emerging technologies for value addition of fish

Retort Pouch Processing

Reportable flexible containers are laminate structures that are thermally processed like a can, are shelf stable and have the convenience of keeping at room temperature for a period of more than one year without refrigeration. The most common form of pouch consists of a 3 ply laminated material. Generally it is polyester / aluminium foil / cast polypropylene. See-through pouches made of polyester/aluminium oxide or silicon dioxide/nylon/cast polypropylene is also available. The manufacture of retort pouch packs involves a series of lengthy operations viz., filling, air removal, sealing, traying and heat processing in an over pressure autoclave

The pouches are heat processed in an over pressure autoclave. Work carried out CIFT has shown that oil sardines packed in retort pouches having composition polyester / aluminium foil / cast polypropylene remained in excellent condition even after a period of 3 years (Ansar Ali et al., 2005). Mackerel in curry packed in indigenous retort pouch and processed to an F_0 value of 8.43 can be kept at room temperature for 18 months in acceptable condition (Gopal *et al.,* 2001). Seer fish in curry medium packed in locally manufactured retort pouches, having a three-layer configuration of thickness 12.5 µm polyester /12.5 µm aluminium foil / 80 µm cast polypropylene with a F_0 value of 11.5 remained in good condition for up to 24 months at room temperature (Ravi Shankar *et al.,* 2002). The flexible pouches manufactured indigenously employing the configuration recommended by CIFT has opened the way for commercialization of fish curry in retortable pouches. The process relies on heat sterilization and in many respects is analogous to canning with the imported tin can being replaced by a cheaper indigenous heat resistant flexible pouch. In comparison with frozen foods, the retort pouch provides a longer shelf life and does not require refrigeration, energy, expensive methods of distribution and storage. No chemical additives are added as most of the bacteria are killed by heat sterilisation. Test marketing of mackerel curry conducted by MPEDA have shown that the product had good acceptability and there is good demand for fish curry in flexible pouches.

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.

High Pressure processing

High Pressure Processing (HPP) is a non-thermal food processing method with application of high pressures (87000 psi or 600 MPa) with or without heating. This is effective to achieve microbial inactivation without significant changes in texture, color, or nutritional value of food. (Hugas *et al.,* 2002; Ross *et al.,* 2003). Application of pressure will be instantaneous and uniform throughout the sample. High Pressure Processing treatment is independent of product shape and size and keeps the natural shape of the product. This method provides an environmentally friendly fresh-like product. HPP with 250 MPa did not inactivate *L. monocytogenes*, but significant lag phases of 17 and 10 d were observed at 5 °C and 10 °C, respectively in cold smoked salmons (Lakshmanan and Dalgaard 2004). Studies carried out at CIFT have shown that HPP of tuna extended the shelf life of tuna for ~10 days when compared to conventional processing methods.

Enzyme treatment

In commercial food processing, transglutaminase (TGase) is used to bond proteins together. It is produced by *S. mobaraensis* fermentation in commercial quantities or extracted from animal blood, and is used in a variety of processes, including the production of processed meat and fish products.TG catalyzes the cross-link of side chains of two amino acids (glutamine and lysine) and thus yielding peptide bond. Examples of foods made using transglutaminase include imitation crabmeat, and fish balls. Transglutaminase can be used as a binding agent to improve the texture of protein-rich foods such as surimi or ham (Yokoyama *et al.,* 2004). It is also used for improving texture of emulsified meat products, such as sausages and hot dogs, binding different meat parts into a larger ones ("portion control"), such as in restructured steaks. Transglutaminase is one of several forms of "meat glue" and help in improving the texture of low-grade meat whose characteristics are attributed to stress and a rapid postmortem pH decline. Seki *et al.* (1990) found that endogenous fish TGase caused suwari setting, or hardening fish protein paste at low temperature by crosslinking. TGase from walleye Pollack used to produce surimi has been purified and characterized by Kumazawa *et al.* (1996).

Extrusion technology

It is a technique used to form shapes by forcing a material through a region of high-temperature and/or pressure, and then through a die to form the desired shape. Food Extrusion is the process of cooking moistened, starchy, proteinaceous food material by the combined action of pressure, temperature and mechanical sheer. CIFT has worked on the production of extruded products by incorporating fish mince with cereal flours. The fish mince is mixed with cereal flours, spices and vegetable oil and extruded using a twin-screw extruded. The product obtained is finally coated

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Pulsed light technology

Pulsed light is a method of food preservation that involves the use of intense and short duration pulses of broad-spectrum "white light". The spectrum of light for pulsed light treatment includes wavelengths in the ultraviolet (UV) to the near infrared region. The material to be treated is exposed to a least 1 pulse of light having an energy density in the range of about 0.01 to 50 J/cm^2 at the surface. A wavelength distribution such that at least 70% of the electromagnetic energy is within the range from 170 to 2600 nm is used. The material to be sterilized is exposed to at least 1 pulse of light (typically 1 to 20 flashes / s) with a duration range from 1 μs to 0.1 s (Dunn *et al.* 1991; 1995; Dunn, 1996). For most applications, a few flashes applied in a fraction of a second provide a high level of microbial inactivation. It acts as a sterilization method for products with uniform surface, packaging materials, pharmaceutical and medical products. As fish has non-uniform surfaces, it cannot sterilize the fish products but reduces microbial load. Pulsed light was effective in inhibiting the growth of *Listeria monocytogens* in vacuum packed smoked salmons (Pollock, 2007). Pulsed light technology has also been shown to be effective in inactivating *L. innocua* from the surface of fish products such as cold smoked salmon (Lasagabaster and Martínez de Marañón, 2006).

Hurdle technology

The concept of hurdle technology is based on the application of combined preservative factors to achieve microbiological safety and stability of foods (Leistner, 1978). The most important hurdles used in food preservation are temperature, water activity, acidity, redox potential, antimicrobials, and competitive microorganisms. A synergistic effect could be achieved if the hurdles hit at the same time at different targets that disturb the homeostasis of the microorganisms present in foods (Leistner, 2000).

For the fish products manufactured in industrialised countries, hurdle technology has been employed for two groups of products (Leroi, 2008). These are:

- Convenience products based on traditional products, like rehydrated salt-cured or dried fish. The raw material is a preserved semi-finished product but as the preservative is removed during processing, surviving pathogens in the raw material may recover. Minimising the survival of pathogens in this product is therefore, beside the hygienic process conditions, necessary to ensure product safety.
- Lightly preserved fish products which are uncooked or mildly cooked products, with low level of preservatives (NaCl < 6% WP, pH >5), such as cold-smoked salmon, carpaccio, slightly cooked shrimp. These products are usually produced from fresh seafood and further processing involves one or a few additional steps that increase risk of cross contamination. The treatments are usually not sufficient to destroy pathogens, and, as several of these products are eaten raw, minimising the presence and prevent growth of pathogens is essential for the food safety.

.**Innovative packaging Technologies**

Modified Atmospheric Packaging (MAP)

Modified Atmospheric Packaging (MAP) is a process by which the shelf life of fish is increased by enclosing it in an altered atmosphere such that it slows down the degradation by microorganisms and development of oxidative rancidity. In practice fish/fish products are packed in an atmosphere of carbon dioxide and other gases like oxygen and nitrogen. MAP chilled fish is an attractive proposition both to the retailer and to the consumer. A number of authors have reported considerable increase of up to two or even three-fold in the shelf-life of fish packed in modified atmosphere compared to that of fish packed in air. (Shalini, 2000; 2001; Ozogul *et al*.,2000,2004; Jeya Shakila et al.,2003; Reddy *et al.*, 1995,1996; Yesudhason *et al.*, 2010).

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 deproteinised 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

Fish processing and value addition has evolved over the years as an important sector in Indian Agriculture. Fish and fishery products earn maximum foreign exchange in the category of agricultural produce exported from India. This sector has immense scope for development through diversification and generation of employment for the skilled and unskilled workforce of the country.

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Seafood Handling and Curing Techniques

Parvathy U.
Scientist
Fishing Processing Division, ICAR- CIFT, Cochin

Fish is a highly regarded food commodity on account of its abundance of high-quality proteins, omega-3 fatty acids, n-3 polyunsaturated fatty acids (PUFAs), essential minerals and vitamins. These nutrients are essential for bodily functions and are beneficial for growth and development of vital organs. Seafood assists in alleviating food crisis across the world, providing valuable supplement to diverse and nutritious diet. Better awareness regarding this biomass as a potential source of nutrients has created increased interest in effectual utilization of these resources. However, their richness in nutrients accounts to its perishability, necessitating their processing and preservation essential immediately after harvest.

Food hygiene relates to "all conditions and measures necessary to ensure the safety and suitability of food at all stages of the food chain". The production of safe and quality fish and fishery products requires effective hygienic practices throughout the food chain from fish harvest to consumption. These hygienic measures aim at preventing or reducing fish contamination and microbial growth covering aspects related to the hygienic design of facilities on-board, during transportation, processing and distribution, to personnel hygiene, cleaning, sanitation and pest control.

Hygienic Onboard Fish Handling

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 maintenance of cold chain. For this:

- Vessels must be designed and constructed so as to protect fish from contamination by bilge-water, sewage, smoke, fuel or other objectionable substances.
- 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.
- Fishing vessels should be designed and equipped with suitable holds, tanks or containers to preserve fresh fish and fishery products throughout the fishing period.
- Chilling devices must allow easy monitoring of temperatures.

- 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.
- All vessels must be kept free of pests using pest control devices.
- 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.
- 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 Domestic Market

Domestic markets play 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

Processing units aims towards value addition 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.

Proper Transportation

During transportation, measures should be taken to protect food from potential sources of contamination and damage likely to render the food unsuitable for consumption. Proper transportation maintaining low temperatures provide an environment which effectively controls the growth of pathogenic or spoilage microorganisms. Care during transportation includes:

- Construction of transportation vehicles and containers such that they can be easily cleaned and disinfected.
- All interior surfaces should be maintained clean, smooth and free of any objectionable odours.
- Vehicles and containers should be maintained at low temperature to ensure cold chain during transportation.

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

CURING TECHNIQUES

Different processing and preservation methods: traditional and modern techniques including salting, drying, smoking, chilling, freezing, thermal processing, chemical treatments, as well as combination of two or more methods (referred to as hurdle technology) are used for fish preservation. Traditional methods of fish preservation include salting, drying, smoking, pickling, marination and fermentation, collectively known as Curing. Curing 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 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

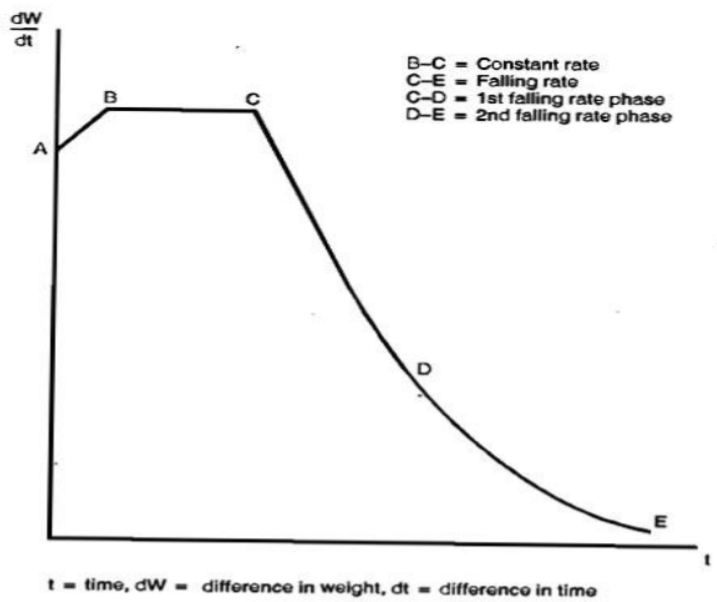
As drying progresses, the water evaporates from the fish surface and is replaced by the water from the interior of the muscles by diffusion. This process is comparatively slower which limits the drying rate and is referred to as the falling rate phase. Drier the product is, slower will be the diffusion 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 “ ”
  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 ° 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.

Drying and salting are age-old practices followed for seafood preservation on account of its simplicity and effectiveness. However, a major drawback with this traditional processing is the lack of standard operating procedures being followed which affects the quality of cured products. Moreover, there is a general a conception that drying/salting is a secondary method for preservation applicable for low value as well as inferior quality varieties. Efforts towards effective and hygienic handling practices in the process chain, popularization of improved drying and packaging practices, and adequate extension services can facilitate better adoption of cured fishery products in the seafood sector. The recent market trends also indicate rejuvenation of this sector on account of the technical advancements being carried out in this area.

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Development of coated and speciality fish products

Sreelakshmi. K.R. and George Ninan
Fishing Processing Division, ICAR- CIFT, Cochin
sreecift@gmail.com

Consumers are looking for better alternative for conventional fresh food that offers time-saving preparation. These food items are called convenient products and the global demand for such products is increasing rapidly. 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.

In essence, a coated food product is one that is coated with another foodstuff. Coating acts as a moisture barrier, minimizing moisture losses during frozen storage and microwave re-heating and retains the natural juices of foods, thereby ensuring a final product that is tender and juicy on the inside and at the same time crisp on the outside. The first commercially successful coated product was fish finger.

There are several ingredients used in the formulation of coatings. Each ingredient performs its functions to contribute to the unique characteristics and functionality of coatings. The commonly used ingredients fall under five categories. They are polysaccharides, proteins, fats, seasonings and water. Besides small quantities of leavening agents, gums, spices, colour etc. may be added to provide specific functional effects. The major ingredients used for the production of batter mix and breadcrumbs are more or less same but the manufacturing techniques employed are different.

Steps in preparation of coated products

Portioning / forming

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

Predusting

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

Battering

Batter is defined as the liquid mixture composed of water, flour, starch, and seasonings into which the fish products are dipped prior to breading. Two types of batter are there- adhesive batter and tempura batter. The adhesive batter is a fluid, consisting of flour and water. Tempura batter is the puff-type batter containing raising/leavening agents. This forms a crisp, continuous, uniform layer over the food. The predusted portions are applied with wet batter and excess batter can be blown off by a current of air. The batter mix helps in governing the amount of bread to be picked up and it contributes to flavour of the final product. Specific ingredients are used to aid viscosity, texture and adhesion. Typical formulation of a batter system is given in Table. 1. The ingredients are classified as critical and optional based on the functions.

Table.1 Formulation of batter

Ingredients	Addition range%
Critical	
Wheat flour	30-50
Corn flour	30-50
Sodium bicarbonate	Upto 3
Acid phosphate	Adjust based on neutralizing value
Optional	
Flours from rice, soy, barley	0-5
Shortening oil	0-10
Dairy powders	0-3
Starches	0-5
Gums, emulsifiers, colours	Less than 1
Salt	Upto 5

Sugars, dextrins	0-3
Flavourings, seasonings etc.	As required

Ingredients of batter mix formulated at CIFT

An adhesive type quick setting batter is usually used. A typical adhesive batter formulated at CIFT, Kochi is given in Table 2.

Table 2.Batter Ingredients

Maida	2000 g
Corn flour	200 g
Bengal gram	200 g
Salt	30 g
Guar gum	5 g
Turmeric powder	5 g
Sodium tripolyphosphate	10g

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

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

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

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

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

The ingredients are mixed evenly and one part of batter powder is mixed with two parts of water to get the required consistency.

Breading

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

Preparation of Bread Crumbs

- Remove the outer brown layer of bread
- Grind in mixer grinder
- Spread over aluminium tray
- Keep for drying for 2 ½ hrs at 70^{0}C in dryer (smoker)
- Store in appropriate packages

Commercial bread crumbs like planko bread crumbs (flake like), extruded bread crumbs (float in oil) etc. can also be used.

Pre-frying/ flash frying

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

Freezing

The first step in preparing the fried fish portion for freezing is air-cooling. This is usually accomplished with the use of a fan or a series of fans. This allows the coating temperature to drop, while at the same time allowing the batter coating to recover from the frying shock and also to stabilize itself. The coated fish portions are then fed to the freezer through conveyor belts. Since the fried portions are fragile, care should be taken to avoid contact between the portions while loading in the freezer. Freezing is usually carried out in spiral freezers. Other types of IQF freezers can also be used depending on the product and convenience. Freezing is completed when the internal and external temperature of the fish portion drop to about – 40°C.

Packaging and storage

The common deteriorative changes taking place during frozen storage of battered and breaded fish products are desiccation, discolouration, development of rancidity etc. Application of proper packaging prevents/retards these changes to a great extent. Conventional packaging materials like flexible plastic films are not suitable for these products as they provide little mechanical protection to the products and as a result the product gets damaged or broken during handling and transportation. Hence thermoformed containers are commonly used for this purpose. The packed coated products are usually stored at –20°C.

Coated fish fillets

Fried coated fish fillet is a prominent food item in the European markets. Along with fried potato chips it forms a substitute for lunch for majority of the floating population in Europe. Fresh water fish fillet of table size and having minimum fin bones can be used for this purpose. Various stages in the production of coated fish fillet are:

Filleting: A fish fillet is a skinless, boneless fish loin cut along the central bone frame and trimmed free of loose or hanging meat. Skinless and boneless fish fillets can be prepared manually as well as using filleting machines. While fillet yield is 30 to 40% with machine filleting, manual filleting gives better yield.

To fillet, keep the fish on the chopping board and cut from behind the pectoral fin down to the main bone and move the knife along the bone frame with minimum loss of meat. Remove the skin along with scales by passing the knife along the skin layer. Also remove the belly flaps. Trim off any hanging meat from the fillet and make it regular and uniform. Wash the fillets in chilled water and drain.

Cold Blanching: Dip the fillets in 5% brine solution containing 0.1% citric acid for 3-5 minutes depending upon the size grade and then drain off.

Pre-dusting: The fillets are then pre-dusted with a suitable pre-dust or dry batter mix itself. The excess pre-dust adhered to the substrate is then removed either by shaking or using an air blower.

Battering: The pre-dusted fillets are then coated with batter uniformly.

Breading: The batter coated fillets are further coated with bread crumbs. Generally medium size porous crumbs having a relatively large granulation are used even though the selection of the crumbs depends upon the requirement of the finished coated product. The bread crumbs are uniformly applied on the product and the excess crumbs are then removed using an air blower. The coating picks up depends on the viscosity of the batter and the type of crumbs and 30-35% is generally obtained.

Pre-frying: After the application of bread crumbs the fillets are flash fried in hot vegetable oil for 20-30 seconds depending on the size grade of the fillets. The temperature of frying is maintained at 180-200°C

Freezing: The flash fried fillets are cooled immediately using a fan and then frozen in an IQF freezer preferably a spiral freezer for the required time depending on the size of the fillets. The time is adjusted by regulating the conveyer speed of the freezer belt.

Packaging: The frozen coated fillets are immediately packed in thermoformed containers or pouches made of 12µm plain polyester laminated with 118µm LDPE. A specified number of such consumer packs are then packed in master cartons.

Storage: The packed cartons of frozen coated fillets are stored in a cold storage maintained at -20°C.

Fish fingers/Fish portions/fish sticks

Fish fingers are regular sized portions cut from rectangular frozen blocks of fish fillet or fish mince. A common size fish block in commercial practice in Europe is 47.9cm long, 25.4 cm wide x 6 cm thick weighing 7.5 kg. On the production line the blocks are subdivided by a series of band saws and subsequently cut into the desired width and shape. Fish fingers are made in to different shapes such as rectangular, square, wedge and french cuts. For small-scale units, frozen slabs of 1.5 cm thick may be convenient for cutting out fish fingers of uniform size. A typical British fish finger normally weighs about 28 g (1 oz) of which up to 50% of the total weight is contributed by the batter and crumbs. Accordingly, a rectangular piece of 7.5 x 2.0 x

1.5 cm weighing about 15 g may give a final weight of 28 g.

The frozen fish block is prepared by mixing fish fillet/mince with 0.6% sodium tripolyphosphate and 1% sodium chloride, placing in a frame of convenient size, pressing slightly and frozen to form a solid block of fixed dimension. (The removal of pin bones from the fillets of fresh water fish of many species is a difficult task. In such cases it will be better to prepare the fish block from the fish mince after removing the pin bones using a fish meat strainer). The frozen block is cut into suitable uniform sizes. These pieces are given a coating of pre-dust, batter and breading as in the case of coated fish fillets. The battered and breaded fish fingers are flash fried in oil at 180-200 $^{\circ}$C for 30 seconds. After cooling, the fingers are frozen preferably in an IQF machine and packed in thermoformed trays or pouches and stored at −20°C. The flow chart for production of fish finger is given in Fig. 2.

The fish fingers when fried in vegetable oil develop a golden brown color with attractive appearance and odour. It has been observed that the sensory quality of fish finger developed from the frozen block of fish fillets is superior to that developed from the block of mince.

Preparation of Fish Fingers

I. *Fish Fingers from Fillet*

Ingredients

Fish fillet	1 kg
Salt	3%

Procedure: Fillet the fish and cut into small pieces (about 10 cm in size) and blanch in 3% salt solution for 10-15 minutes. Drain off and pre-dust with batter powder and coat with batter and breadcrumbs and fry.

II. *Fish Fingers from Mince*

Ingredients

Fish fillet	1 kg
Tri-sodium polyphosphate	0.1 %

Salt	0.6 %

Procedure: Dress and fillet the fish and mince in a meat mincer. Add 0.1 % tri-sodium polyphosphate, 0.6% salt, mix, spread the mince in a tray uniformly and freeze. Cut into small pieces (about 10 cm in size) in the frozen condition itself. Pre-dust the finger with batter powder and coat with batter and breadcrumbs using a bamboo stick. The battered and breaded fish fingers are flash fried in oil at 180-200°C for 30 seconds. After cooling, the fingers are frozen preferably in an IQF machine and packed in thermoformed trays or pouches and stored at −20°C.

The fish fingers when fried in vegetable oil develop a golden brown color with attractive appearance and odour. It has been observed that the sensory quality of fish finger developed from the frozen block of fish fillets is superior to that developed from the block of mince. The removal of fin bones from the fillets of fresh water fish of many species is a difficult task. In such cases it will be better to prepare the fish block from the fish mince after removing the fin bones using a fish meat strainer

Fish Cutlet

Fish cutlet has become a popular snack at celebrations, household functions, tea times etc. The basic raw material required for preparation of this product is cooked fish meat generally from less costly fishes with white meat or cooked meat from skeletal frame obtained after filleting of fish.

Ingredients

Cooked fish meat	:	1000 g
Salt	:	25 g (approx.)
Oil	:	125 ml
Green chilli	:	20 g
Ginger	:	25 g
Onion	:	250g
Potato (cooked)	:	500g
Curry leaves	:	20 g
Mint leaves	:	20 g
Pepper (powder)	:	3 g
Clove (powdered)	:	2 g
Cinnamon (powdered)	:	2 g
Turmeric	:	2 g

Batter mix	:	250 g
Bread crumb	:	300 g

Method of preparation

- Cook the dressed fish /skeletal frame/mince in 2% brine for 30 minutes and drain off the water
- Remove the skin, scales and bones and separate the meat
- Mix the meat well with a little salt and turmeric powder in a homogenizer
- Fry chopped onions in oil till brown. Add curry leaves, chilly and ginger in chopped form and mint in blended form and fry. Mix these with the cooked meat
- Add mashed potato and spices and mix well with the cooked meat
- Adjust the salt content to taste and shape 30 g each in round or oval form manually or using a forming machine
- Batter with batter mix dispersed in water in the ratio 1: 2 and roll in breadcrumbs
- Freeze the cutlets preferably in an IQF machine.
- Pack in thermoformed trays/pouches and store at –20 °C.

Fish Balls

There are several varieties of fish, which do not command a ready market as fresh fish, but are comparable to many table fish in nutritive value and other attributes. One of the ways of ensuring effective utilization of such fish is to process ready-to-serve or ready-to-cook value added `convenience' products, for which there already exists great demand. Fish ball is one such product prepared using fish mince and starch that can be processed as a coated product or as a heat-processed product in a suitable fluid medium. Coated fish ball is a palatable and nutritious product prepared from mince of low cost fishes. The preparation of fish ball is simple and requires only few locally available ingredients. Hence it is an ideal product for small scale units.

Ingredients

Fish mince : 1000g Corn
starch : 50g

Ginger : 20g

Garlic	:	20g
Pepper	:	2g
Salt	:	10g (1%)
Batter	:	250 g
Bread crumbs	:	350 g

Process

- Allow the frozen fish mince to thaw. Wash the mince and drain.
- Add corn starch and salt to fish mince and mix thoroughly.
- Add ginger and garlic made into a paste along with pepper powder and mix thoroughly.
- Prepare balls of size 2-3 cm diameter.
- Cook in 1% boiling brine for 10 minutes.
- Take out, drain and cool.
- Pre-dust the balls with the dry batter mix
- Using a bamboo skewer dip in batter prepared in the ratio 1:2 with water
- Apply bread crumbs
- Flash fry in vegetable oil
- Pack the balls in thermoformed trays
- Freeze at -40°C (z IQ) -20°C

Preparation of Specialty Products from Shrimp

Centre-peel shrimp

Raw Material: Prawn 26/30 to 31/40 counts/kg

Process: Wash the whole shrimp in potable water. Peel at the centre retaining the head, the last segment and the tail fans. De-vein by inserting a pointed needle or pointed bamboo stick between the segments dorsally and lifting off the vein. Remove the telson by gently raising upwards. Trim off the head and tail fans to reduce the sharpness to avoid damage of the package. Arrange in PVC/polystyrene trays and vacuum pack in laminated pouches. Blast freezing at –40°C & storage below -18°C in master carton.

Cooked centre peel shrimp

Raw Material: Prawn 26/30 to 31/40 counts/kg

Process: Wash the whole shrimp in potable water. De-vein by inserting a pointed needle or pointed bamboo stick between the segments dorsally and lifting off the vein. Remove the telson by gently raising up wards. Cook the shrimp in 1% boiling brine for 2-3 minutes depending on the size grades. Cool in chilled water. Peel at the centre retaining the head, the last segment and the tail fans. Trim off the head and tail fans to reduce the sharpness to avoid the damage of the package. Arrange in PVC/polystyrene trays and vacuum pack in laminated pouches. Blast freezing at –40ºC & storage below -18°C in master carton.

Easy-peel shrimp

Raw Material: Prawn 26/30 to 31/40 counts/kg

Process: Wash the whole shrimp in potable water and remove the head. De-vein by inserting a pointed needle or pointed bamboo stick between the segments dorsally and lifting off the vein. Remove the telson by gently raising up wards. Cut the cuticle, up to end of the last segment dorsally or laterally leaving it intact, just to make the cooked shrimp easy to peel. Arrange in PVC/polystyrene trays and vacuum pack in laminated pouches. Blast freezing at –40ºC and storage below -18°C in master carton.

Cooked easy-peel shrimp

Raw Material: Prawn 26/30 to 31/40 counts/kg

Process: Wash the whole shrimp in potable water and remove the head. De-vein by inserting a pointed needle or pointed bamboo stick between the segments dorsally and lifting off the vein. Remove the telson by gently raising up wards. Cook the shrimp in 1% boiling brine for 2-3 minutes depending on the size grades. Cool in chilled water. Cut the cuticle, up to the end of the last segment dorsally or laterally leaving it intact. Arrange in PVC/polystyrene trays and vacuum pack in laminated pouches. Blast freezing at –40ºC and storage below -18°C in master carton.

Shrimp skewer

Raw Material: Prawn 26/30 to 31/40 counts/kg

Process: Wash the whole shrimp in potable water and remove the head. Remove the telson by gently raising upwards. Peel the shrimp completely, including the tail fans and de-vein. Arrange 4-5 "U" P / trays and vacuum pack in laminated pouches. Blast freezing at –40°C and storage below -18°C in master carton.

Major Markets: Japan, US and Europe

Fantail round

Raw Material: Prawn 26/30 to 31/40 counts/kg

Process: Wash the whole shrimp in potable water and remove the head. Remove the telson by gently raising up wards. Peel the shrimp leaving the shell intact on the last segment and the tail fans. De-vein the shrimp and trim the tail fans using a pair of scissors. Arrange in PVC/polystyrene trays and vacuum pack in laminated pouches. Blast freezing at –40°C and storage below -18°C in master carton.

Coated fantail round

Raw Material: Fantail round shrimp pre-dust, batter and bread crumbs.

Process: Coat the Fantail round shrimp with a thin layer of pre-dust either manually or using a pre-dusting machine. Coat the pre-dusted shrimp either with a conventional (adhesive) batter or a tempura type batter, depending upon the market. Coat the battered shrimp with breading (Japanese style light coloured coarse crumbs for Japan Markets and darker coloured crumbs (yellow-orange) U P / , " " vacuum pack in laminated pouches. Blast freezing at –40°C and storage below -18°C in master carton.

Butterfly shrimp

Raw Material: Prawn 26/30 to 31/40 counts/kg

Process: Wash the whole shrimp in potable water and remove the head. Remove the telson by gently raising up wards. Peel the shrimp leaving the shell intact on the last segment and the tail fans. De-vein the shrimp and trim the tail fans using a pair of scissors. Cut through the dorsal side length-wise using a sharp scalpel or knife (Butterfly cut) to partially separate the lateral muscle block. Gently open up the cut surface to reveal the butterfly shape. Arrange in PVC/polystyrene trays and vacuum pack in laminated pouches. Blast freezing at –40°Cand storage below -18°C in master carton.

Coated butterfly shrimp

Raw Material: Butterfly shrimp pre-dust, batter and bread crumbs.

Process: Coat the butterfly shrimp with a thin layer of pre-dust either manually or using a pre-dusting machine. Coat the pre-dusted shrimp either with a conventional (adhesive) batter or a tempura type batter, depending upon the market. Coat the battered shrimp with breading (Japanese style light coloured coarse crumbs for Japan Markets and darker coloured crumbs (yellow-orange) U P / , “ ” vacuum pack in laminated pouches. Blast freezing at –40°C and storage below -18°C in master carton.

Butterfly "sushi" shrimp

Raw Material: Prawn 26/30 to 31/40 counts/kg

Process: Wash the whole shrimp in potable water and remove the head. Remove the telson by gently raising upwards and de-vein. Insert bamboo skewer along the dorsal side length-wise up to the last segment so as the stretch the shrimp completely. Blanch/lightly cook in 1% boiling brine for 1-2 minutes depending on the size grades. Cool in chilled water. Peel the cooked shrimp completely, including the tail fans. Cut the gently down the ventral side length-wise up to the last segment using a sharp scalpel or knife without damaging the lateral muscle blocks on either side. Gently open up the cut surface to form the butterfly shape. Arrange in PVC/polystyrene trays and vacuum pack in laminated pouches. Blast freezing at –40°C and storage below -18°C in master carton.

Stretched shrimp (Nobashi)

Raw Material: Prawn 26/30 to 31/40 counts/kg

Process: Wash the whole shrimp in potable water and remove the head. Remove the telson and trim the tail fans. Peel the shrimp, leaving the shell intact on the last segment and the tail fans. Make three or four parallel cuts, across or diagonally on the ventral side using a sharp razor. Stretch the shrimp to the desired length by gently pressing it using a stainless steel mould. Arrange in

P / , “ ”
freezing at –40ºC and storage below -18°C in master carton

Breaded “Nobashi”

Raw Material: Stretched shrimp (Nobashi), pre-dust, batter and bread crumbs.

Process: Coat the stretched shrimp with a thin layer of pre-dust either manually or using a pre-dusting machine. Coat the pre-dusted shrimp either with a conventional (adhesive) batter or a tempura type batter, depending upon the market. Coat the battered shrimp with breading (Japanese style light coloured coarse crumbs for Japan Markets and darker coloured crumbs (yellow-orange) U P / , “ ” vacuum pack in laminated pouches. Blast freezing at –40ºC and storage below -18°C in master carton.

Shrimp single kebab (barbecue)

Raw Material: Prawn 26/30 to 31/40 counts/kg

Process: Wash the whole shrimp in potable water and remove the head. Peel the shrimp completely and devein. Insert a bamboo skewer along the dorsal side length-wise up to the last segment so as to stretch the shrimp completely. Arrange the skewered shrimp in PVC/polystyrene trays and vacuum pack in laminated pouches. Blast freezing at –40ºC below -18°C in master carton

Shrimp vegetable kebab

Raw Material: Shrimp (any species), carrots, onion and capsicum.

Process: Wash the whole shrimp in potable water, remove the head, Peel and de-vein. Blanch in 1% boiling brine for 15-30 seconds and cool in chilled water. Wash the vegetables in potable water and dice to approximately 2 cm cubes or cut into square pieces and blanch in 1% boiling brine for 30-60 seconds and cool in chilled water. Arrange in skewer, shrimp alternating with diced vegetables. Arrange the skewered shrimp vegetables in PVC/polystyrene trays and vacuum pack in laminated pouches. Blast freezing at –40ºC and storage below -18°C in master carton

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Thermal Processing and RTE (Ready to Eat) Products: An Overview

C.O. Mohan
Senior scientist
Fishing Processing Division, ICAR- CIFT, Cochin

Processing and preservation of food is an important activates 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

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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 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

‘ ’

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

‘ ’

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.

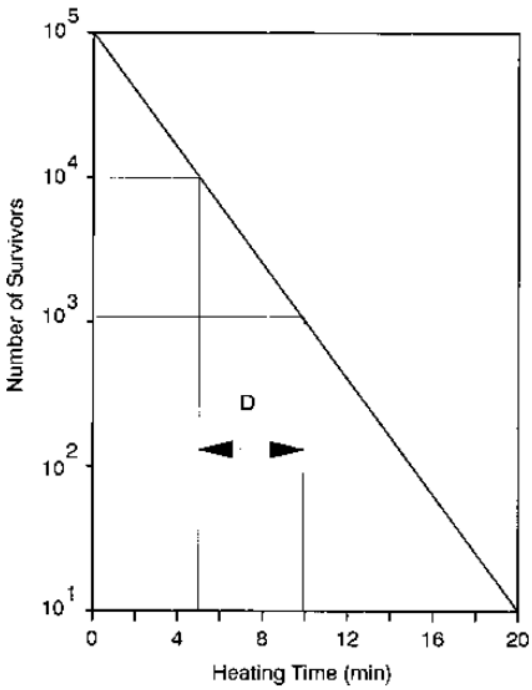


Fig 1. Survivor curve

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

‘z’ ,

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 ‘z’ sensitivity indicator is usually taken as 10°C in the case of *C.botulinum.*

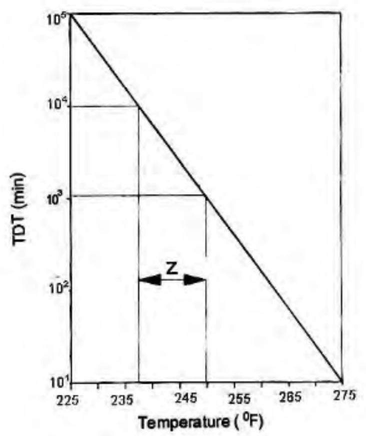


Fig. 2 TDT Curve

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.,

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

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

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 N_o/N_t ‘ ’, ‘ ’
‘ ’ ‘ ’ :

$$F_0 = mD_{121.1°C}$$

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 ‘ ’ I , O / HO x 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 ‘ ’ reater 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 int ‘ ’

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 t ‘ ’

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

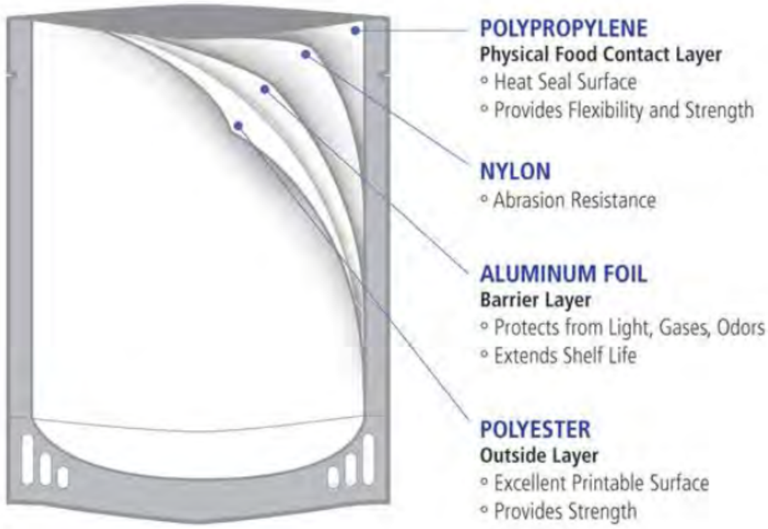
- Thin cross- sectional profile – hence rapid heat transfer – 30-40% saving in processing times – no over heating of the product near the walls
- Better retention of colour, flavour and nutrients
- Shelf life equal to that of the same product in metal can
- Very little storage space for empty pouches – 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

Containers used for thermal processing



Composition of Retortable pouch

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.

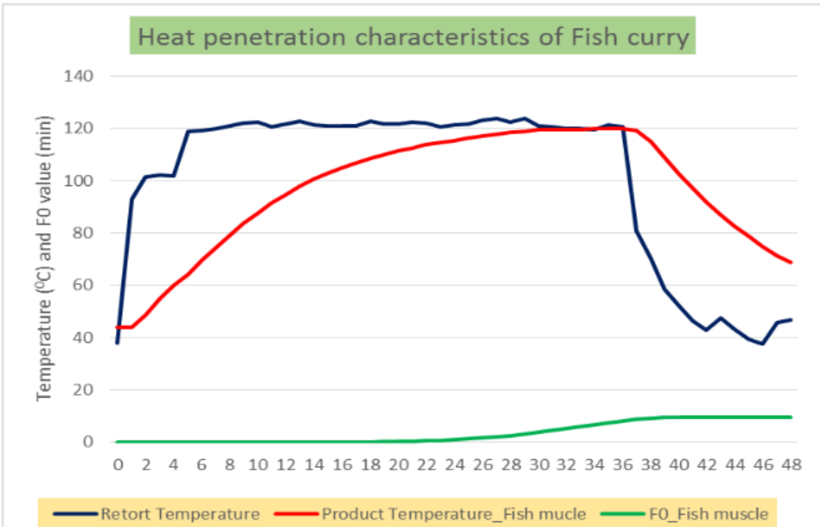
Fishery products, being categorized as low acid foods require heat processing severity with respect to *C botulinum* and F_0 value recommended is 5-20 min. Thermal processing of fishery products include various steps. These steps include, preparations like washing, beheading, gutting, removing scales / 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

Steam retort and water immersion retort



Typical heat penetration curve of fish curry in retortable pouches

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CIFTFISHPRO

Dr. Joshy C G

scientist

Fishing Processing Division, ICAR- CIFT, Cochin

joshy.cg@icar.gov.in

Dissemination of technologies to the end-user is an integral part of any research and development organization. ICAR-Central institute of fisheries technology (ICAR-CIFT) has developed and optimized various value-added fish products for the better utilization of fishery resources, to support the livelihood of fishers and to transfer the services to the stakeholders through teaching, training and agribusiness incubation programs. In this era of digitalization and online services, development of user-friendly applications for the dissemination of technology to the users would enhance their knowledge, to help the entrepreneurs or stakeholder to plan, design and execute the development of value-added fish products.

CIFTFISHPRO is a web-based information system on a series of value-added fish products, listing the required ingredients and the stepwise method of preparation of the products. One of the major features of the application is that it will help the user to quantify the ingredient requirement when the product is taken up for up-scaling and also determines the approximate cost of production for a given quantity of raw fish. Further, the system gives an option to the user to enter the input cost of the ingredients and the user gets a broad idea on the total cost incurred while up-scaling the product. Users can also use the application to communicate with the experts at CIFT, to answer their queries. Moreover, development of value-added fish products enhances nutritional security and boosts the livelihood and entrepreneurship options of the weaker sections of the society.

The system was developed in hypertext preprocessor (PHP) and designed using hypertext markup language (HTML) and Cascading style sheets (CSS). The algorithm for up-scaling the product was implemented in JavaScript (JS). CIFTFISHPRO being a web-based application can be accessed from any arbitrary platforms using the internet; this would help the entrepreneurs or stakeholder to plan, design and execute the development of value-added fish products optimally.

CIFTFISHPRO is an interactive software with simple and easy navigation to access the contents; the web version is available at http://ciftfishpro.cift.res.in/index.php and the android application can be downloaded from google play store at https://play.google.com/store/apps/details?id=com.icar_ciftfishpro&hl=en_IN&gl=US.

The web based system starts with a home page navigating to information about series of value added fish products including description about the product, active ingredients of the products and brief on its method of preparation. It also includes up-scaling option for each product. The home page includes a slider to showcase the products banner and a menu bar redirecting to system description, fish products and contact option as given in figure 1.

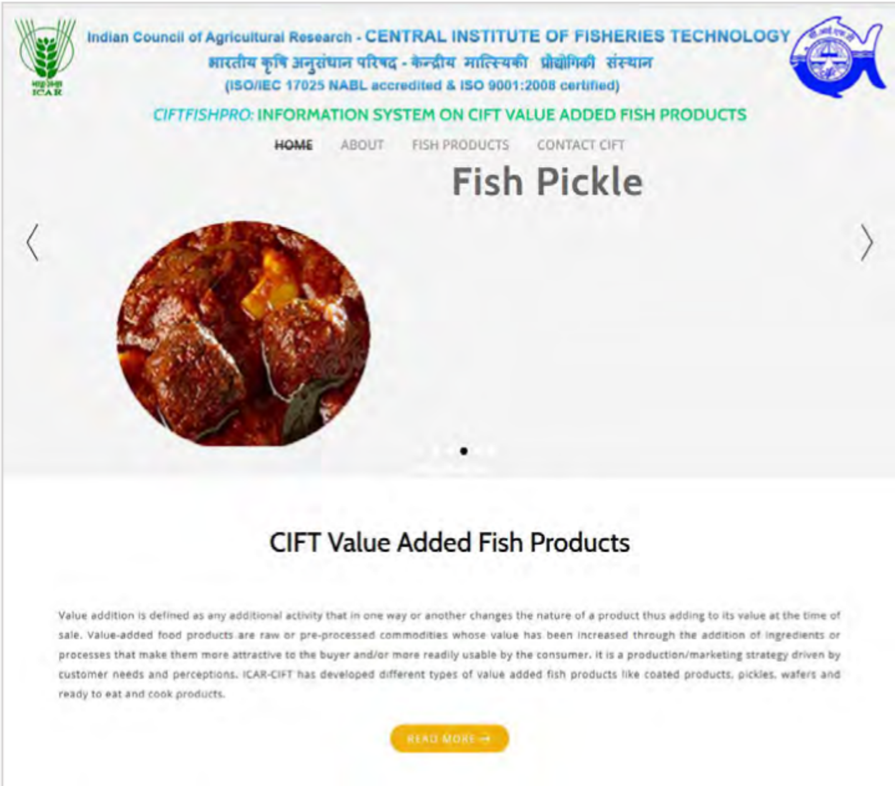

Figure 1. Home page of CIFTFISHPRO

Figure 2 shows the fish products section; it displays the various value-added fish products developed by ICAR-CIFT. The series of fish products includes coated fish products (fish cutlets, fingers, burger, balls etc.), wrapped fish products (fish momos, kebabs, samosa and rolls), marinated products (fish and prawn pickles), extruded products (fish kure and noodles), cured products (dried fish and prawn) and other products like fish sausage and prawn chutney powder etc.

Figure 2. List of value added fish products

On clicking the fish products, it redirects to a webpage with the product description, the required ingredients and the method of preparation as in Figure 3.

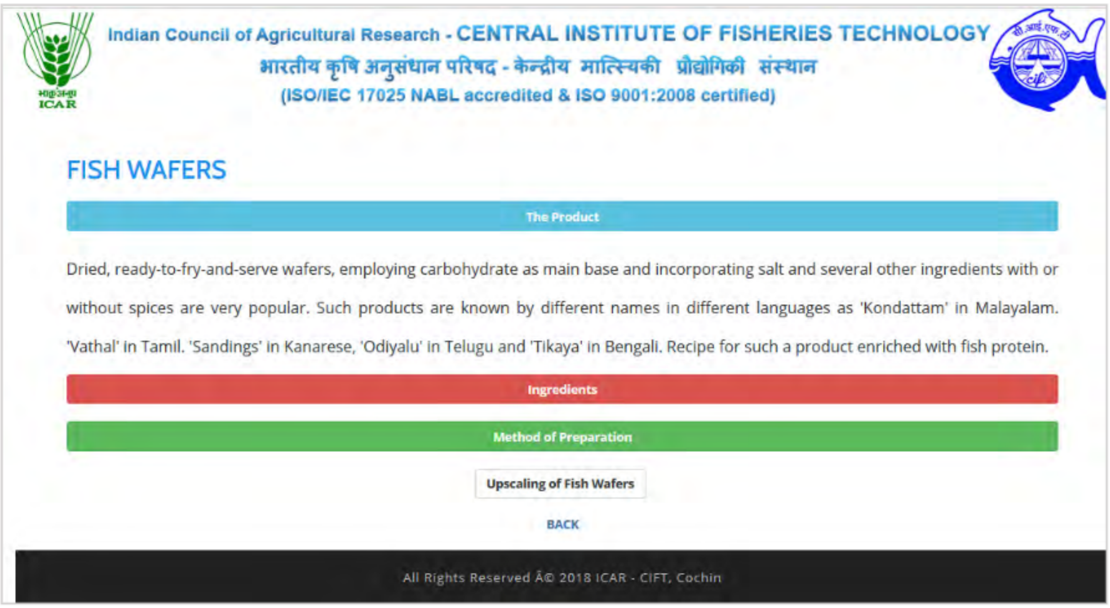

Figure 3. Inner page of fish wafers

Further it contains the up-scaling page for each product. Figure 4 shows the up-scaling page for the fish products.

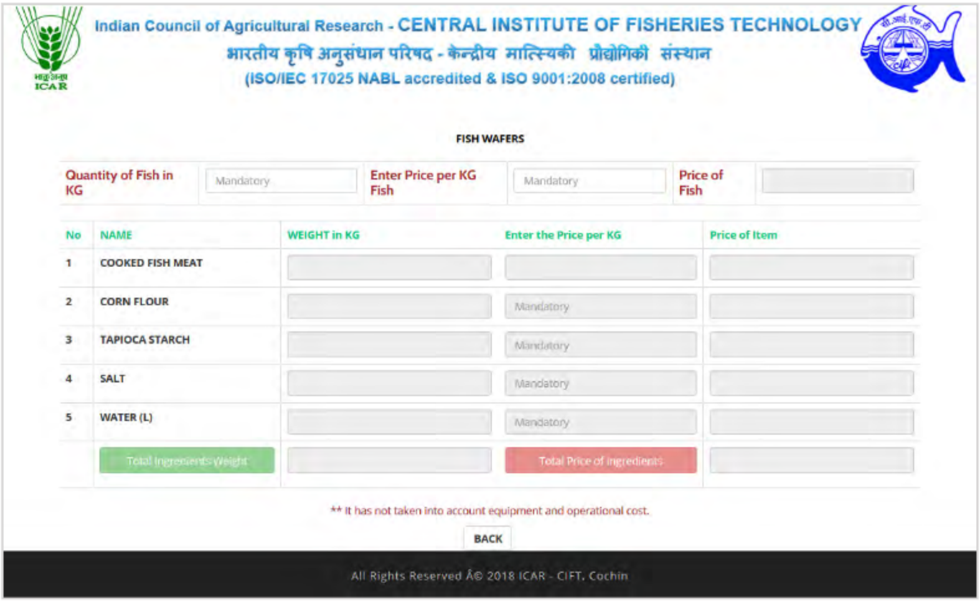

Figure 4. Up-scaling page of fish wafers

For example, on clicking fish wafers link, it gives a brief description about fish wafer, the active ingredients in fish wafer and the step-by-step method of preparation as illustrated in figure 3. The system also provides an option for the up-scaling of the fish wafer as in Figure 4.

The contact CIFT link contains the contact form, ask the expert as in Figure 5. Using the contact form, the user can post the queries along with their name and e-mail id; this would enable the experts from CIFT to give instant replies to the query.

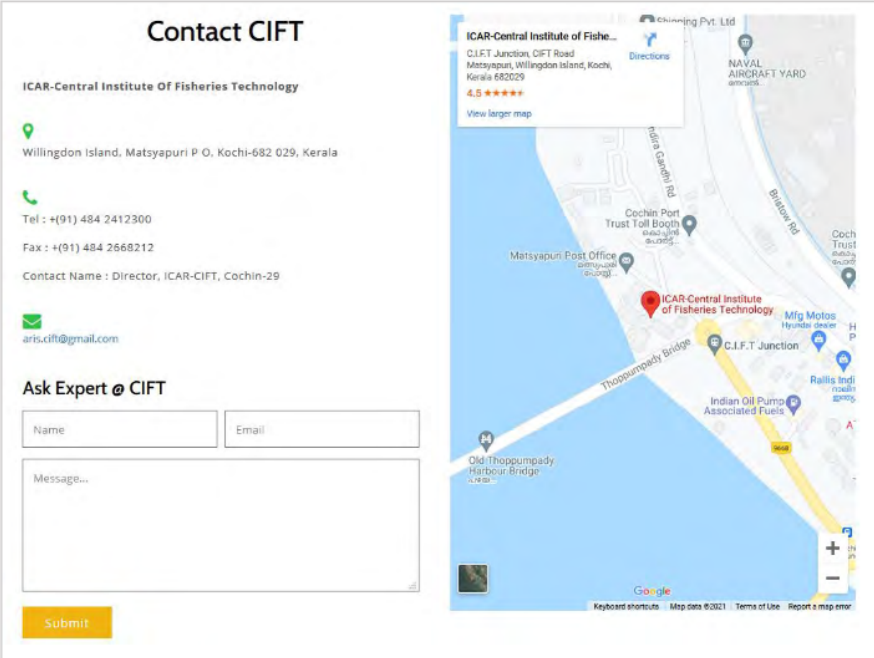

Figure 5. Ask the expert contact form in CIFTFISHPRO

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Non-thermal food preservation techniques: Scope and future perspectives

Remya S. & Bindu J.
Fishing Processing Division, ICAR- CIFT, Cochin
remya03cof@gmail.com

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.
- Destruction of nutritional components of food and the consumer demand for convenient, high quality, and minimally processed food products are the two key drivers towards innovation of the non-destructive/non-thermal food technologies.
- Non-thermal food processing simply refers to methods where the food materials receive microbiological inactivation without the direct application of heat.
- They are relatively young technologies, which use mechanisms other than conventional heating to reduce or eliminate microorganisms. Hence it offers an alternative to conventional thermal processing.

Categorization of non-thermal preservation techniques (Pivarnik and Worobo, 2014)

- High-pressure processing
- Light (ultraviolet, pulsed light)
- Ionizing radiation (gamma irradiation, electron beam)
- Gases (ozone, chlorine dioxide, cold plasma)

- There are other techniques like Pulsed Electric Field (PEF) processing, Ultrasound processing, Dense phase carbon dioxide (DPCD) processing etc.

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 (≤100 P)
- 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.
- 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 press 250 MP given to pink perch mince samples added with and without MTGase enzyme, for a holding 12 mi 25 °C 30 mi 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- (300 P 5 mi) - 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. Th $(p < 0.05)$ - 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 16^{th} day in refrigeration condition.
- Ginson et. al. (2020) investigated the piezotolerance and diversity indices of microflora of Indian white prawn (Fenneropenaeus indicus) after high pressure (HP)-treatment. *Arthrobacter spp., Listeria grayi* and *Corynebacterium spp*. were the most piezo tolerant bacteria in HP-treated samples. 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

- o 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.
- o 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.
- o HPP (>200)
- o 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*
  - o Foods with entrapped air or with insufficient low moisture content will be crushed or compacted under high pressure.
  - o 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

- o PEF is an efficient non-thermal food processing technique using short, high voltage pulses.
- o It is used for inactivation of spoilage and pathogenic microorganisms in various food products. Electric pulses are applied for destroying harmful bacteria in food.
- o Microbial inactivation is achieved by dielectric breakdown of the bacterial membranes
- o 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.
- o It enhances the shelf life of the food without quality loss.
- o 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.
- o 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- 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

D L	D	A
	<1	I , I , ,
	1–10	x , , q

H	>10	H z , , z q

Labelling requirements

- For ionizing radiation, information concerning its application to the food and/or one of the ingredients of the food is mandatory.
- “ z ” , “ z ”, “ ” x “ ”, x H , 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 12th 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.

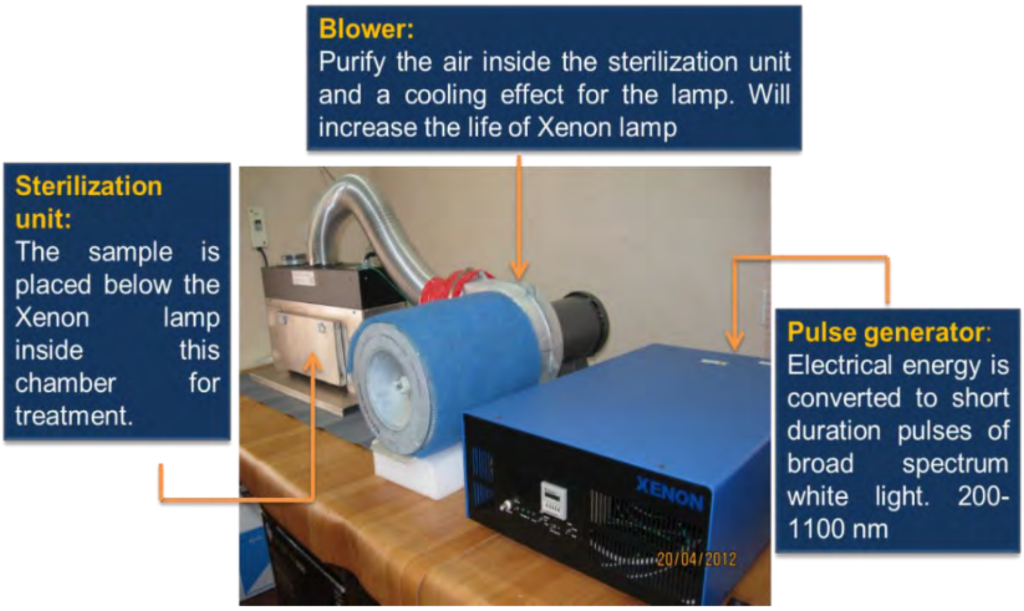

Figure 1: Pulsed Light Equipment of CIFT

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

- 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.
- , x P “ ”
  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.
- US is sound wave bearing certain frequency that is more than the normal human hearing frequency, which is more than 20 kHz.
- 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 °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 o ’ 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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Smoke-Drying Technology for Fish Preservation

Sathish Kumar K
Scientist
Fishing Processing Division, ICAR- CIFT, Cochin

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

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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.

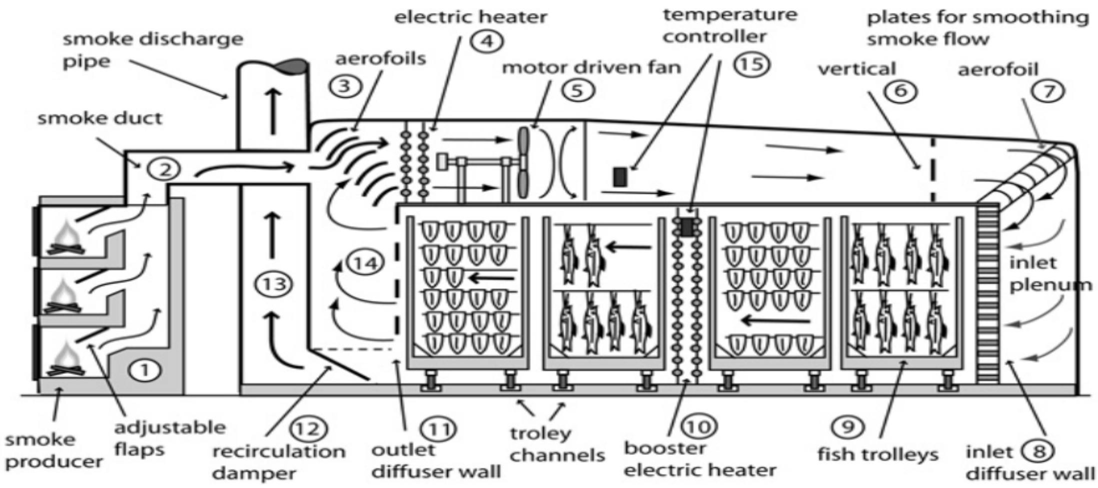

Fig. Illustration of the hot smoke airflow in the Torry smoking kiln

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.

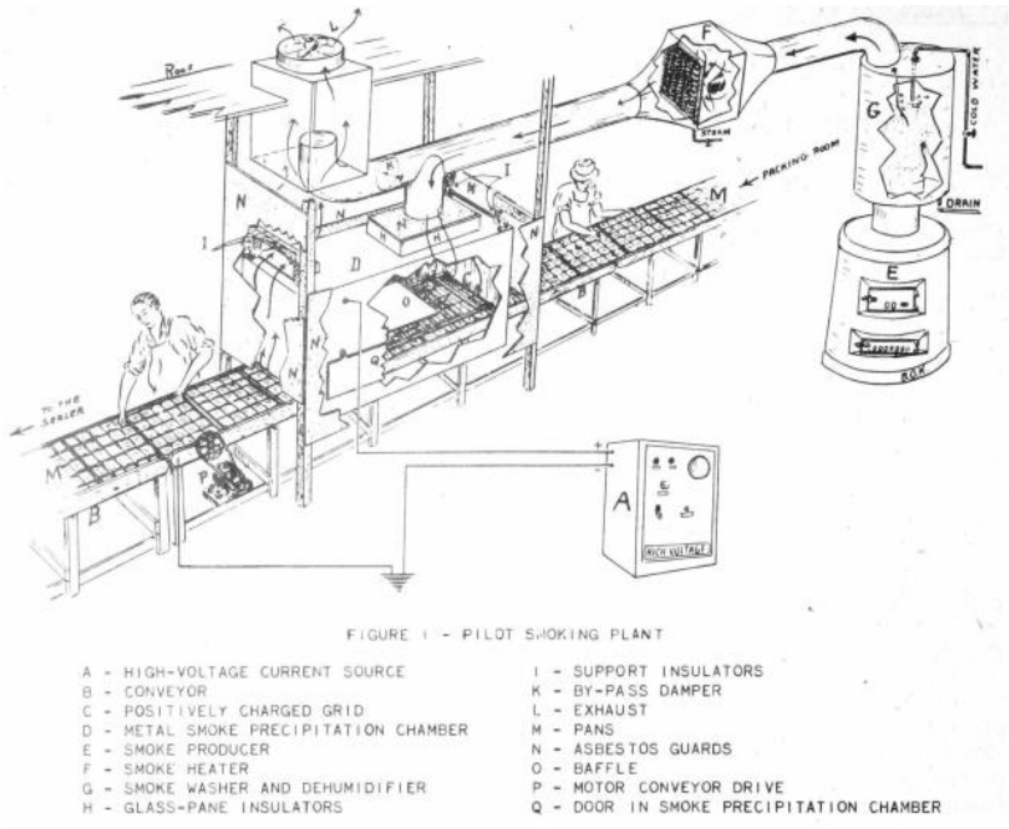

Fig. Schematic diagram of Electrostatic smoking with basic components.

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.

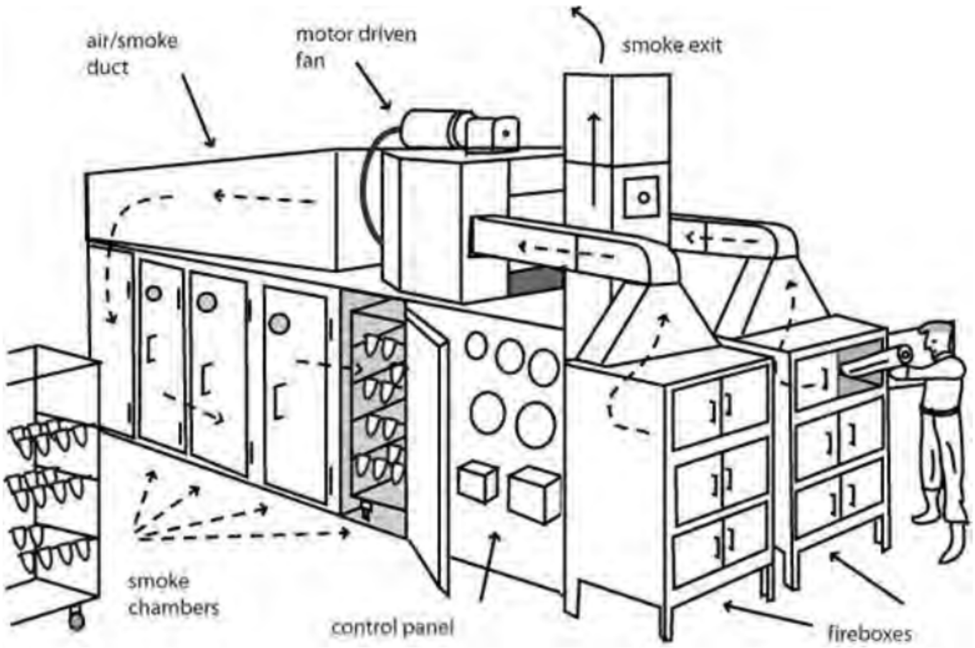

Fig. Smoking kiln

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 22-28° 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° 2-3 h) can inactivate the *L. monocytogens* effectively, provided the raw material is not extra-ordinarily contaminated with the bacteria prior to processing. At the same time listericidal process should be validated to ensure that the treatments are effective and can be applied continuously. But the hot smoked products are susceptible to post-process contaminations from many of the micro-organisms due to improper handling and storage of the products. Sufficient heat treatment, proper hygienic handling and cold chain maintenance during distribution can reduce the risk of biological hazards in smoked fish and fishery products.

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

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

II. Chemical hazards

1. Polycyclic Aromatic Hydrocarbons (PAHs)

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

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

2. Histamine:

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

3.Biotoxins:

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

III. Physical Hazards

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

IV. Other potential hazards associated with smoking of fish

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

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Packaging of Fish and Fishery products

J. Bindu,
Principal Scientist
Fishing Processing Division, ICAR- CIFT, Cochin

1.0 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.

2.0. Types of Packaging Material

2.1. 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.

2.2. 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.

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.

2.3. 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.

2.3.1. 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.

2.4. 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.

2.4.1. 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.

2.4.2. 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.

2.4.3. 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.

2.4.4. 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.

2.4.4.1. 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.

2.4.4.2. 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.

2.4.5. 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.

2.4.6. Polyester

Polyester can be produced by reacting ethylene glycol with terephthalic acid. Polyester

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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.

2.4.7. 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.

2.4.8. 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.

2.4.9. 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.

2.4.10. 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.

3.0. 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.

3.4. 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.

3.4.1. 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.

3.4.2. 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.

3.4.3. 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.

3.4.4. 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.

3.4.5. 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.

3.5. 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.

3.6. 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.

3.8. 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.

3.9. 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.

3.10. 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.

3.8. 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.

3.9. 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.

3.10. 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.

3.11. 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.

3.12. 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.

3.13. 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.

3.14. 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.

3.15. 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.

3.16. 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.

3.17. 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

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High value secondary products from Industrial seafood processing waste

A. Jeyakumari
Scientist,
Fishing Processing Division, ICAR- CIFT, Cochin
jeya131@gmail.com

Processing of seafood for human consumption results in enormous quantity of waste in the form of skin, head, viscera, scales, bones, trimmings and frames. The quantity of waste generated depend on the type and size of fish and the product manufactured out of it. Industrial fish processing for human consumption yields only 40% edible flesh and the remaining 60% is thrown away as waste. Annual discard from the world fisheries were estimated to be approximately 20 (25%) “ ” -products also. Fishery waste is prone to faster spoilage since it contains easily digestible protein. The microbial population associated with the digestive process are the major reasons of spoilage. Since the processor does not bother to preserve the waste the problem of environmental pollution is enhanced. Accumulation of fishery waste results in nauseating and obnoxious smell due to the release of volatile nitrogenous compounds during decomposition.

The immense scope for high end product from fishery waste has been realized and different technologies have been developed with a view to utilize processing waste, for converting them into products for human consumption, animal nutrients and products of pharmaceutical and nutraceutical significance. The fish waste utilization technology evolved by ICAR-CIFT helps to eliminate harmful environmental effects and improve quality in fish processing. Research carried out at the Central Institute of Fisheries Technology, Cochin, paved the way for production of valuable food and industrial products namely protein extract, chitin, chitosan and its derivatives and glucosamine hydrochloride from the head and shell waste of prawns, crab and squilla.

Nature and composition of secondary raw materials from seafood processing

In seafood industry, the general understanding is that the edible meat part constitute forms the ‘ ’ and the remaining parts including head, trimmings, skin, viscera, scale, bone etc. ‘ ’, ‘ / ’ quantum of secondary raw materials generated in seafood industry depends on several factors, which may be broadly categorised into resource related factors and process related factors. The former category includes species, size, age, biological nature (including presence of toxins and allergens) and morphological features. Generally, 40- 70% of original raw material is discarded in commercial processing operations depending on intended product, style of dressing, type of handling (manual/ mechanical), skill of handling person, intended use and to a greater extent on the quality of raw material. Largely, seafood processing operations generate both liquid and solid wastes; solid waste being the bulk ranging from 30% to 65% of the weight of the landed fish. Head, viscera, skin, fin, swim bladder, bone, frame meat, dark meat, scale, gills, shells (crustacean, mollusca), cephalopod pen, ink sac etc. are the major components of solid waste. The liquid effluents mainly consist of blood, slime, mucus, wash off and other soluble. In surimi processing, soluble proteins are washed off to a greater extent during repeated water washing steps.

Table 1. Percentage of waste generated (%) during seafood processing

Products	**Waste Generated (%; w/w)**
Shrimp products (peeled and deveined, peeled and undeveined, Headless etc.)	50
Fish fillets	70
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

Table 2. Seafood products and their respective waste

Major Sea food Products	Major Waste	Major Compounds
Fish based Product	Head, frames, skin, intestine, roe, tails, fins, scales, etc.	Protein, fat, Minerals, enzymes, Chondroitin, Fe
Shrimp based products	Carapace (head) Telson (tail) Rostrum Antennae Appendages Eggs Cook juice	Chitin, Protein, Pigments
Frozen Squid (Whole Cleaned, Fillet, Rings	head behind the tentacles Visceral mass Beak Ink sac and ink Squid pen Skin membrane	Protein, Enzymes, Melanin, Chitin
Cuttlefish (Whole cleaned, deskinned	head behind the tentacles Visceral mass hard Beak Ink sac and ink Cuttle bone Skin membrane	Protein, Enzymes, Melanin, Chitin
Lobster Meat	Lobster shell Appendages	Chitin
Pasteurized crab meat	Crab shell	Chitin Pigments
Fish products (fillet, surimi)	Head Frame/bone Skin Scales Gills Fins Visceral mass Wash water	Proteins Lipids Enzymes Minerals
Frozen clam/Mussels	Shells Shuck water	Calcium oxide Protein

Fish meal

Fish meal is highly concentrated nutritious feed supplement consisting of high-quality protein, minerals, vitamins of B group and other vitamins and other unknown growth factors. Fishmeal is rich in essential amino acids. It is produced by cooking, pressing, drying and grinding the fish, by-catch fish, miscellaneous fish, filleting waste, waste from canneries and other processing operations. The composition of fishmeal differs considerably due to the variations in the raw material used and the processing methods and conditions employed. Traditional fishmeal production in India was from the sun-dried fish collected from various drying centers and the products were mainly used as manure. Better quality fish meal has been a prominent item of export from the very beginning of this industry. BIS has brought out the specification for fish meal as live stock feed for facilitating proper quality control. As per FAO projection, by 2025, fish meal produced from fish waste will represent 38% of world fish meal production, compared with 29% for the 2013 to 2015 average level.

The proximate composition of fish meal in general is given below:

Protein - 50-57%

Fat - 5-10%

Ash - 12-33%

Moisture - 6-10

Fish body oil

The main source of fish body oil in India is oil sardine. A survey of the oil industry reveals that the extraction is done on a cottage scale in isolated places near the leading centers and is not well organized. The method of extraction followed is cooking the fish in iron vessels and pressing and separating the oil. Apart from sardine oil, fish body oil is also obtained from the fish meal plants operating in the country. In India oil sardine is a fishery which exhibited wide fluctuations from as low as 1% to as high as 32% of the total landings. The seasonal variation in oil content is predominant in Kerala and Karnataka coast. During the peak season fish has oil content of 17%. By the wet rendering process the fish will yield, on average 12% oil having analytical characteristics similar to other fish oils. Fatty acid composition of oil revealed that they contain high amounts of polyunsaturated fatty acids (PUFA). At present the medicinal values of fish oils are well known.

Fish liver oil

The therapeutic value of fish liver oil was discovered in 18th century and fish liver oil become a common medicinal product especially for Vitamin A and D. Cod, shark and haddock livers are the important sources of Vitamin A and D. The weight of liver, fat content and presence of vitamins are dependent on a number of factors like species, age, sex, nutritional status, stages of spawning, and area from where it is caught. In cod (Gadus collarius), coal fish (Pollahius vireus) and haddock (Melanggrammus aenglefinus), the weight of liver normally amount to 4-9% of whole fish and livers contain about 45% to 67% oil. The species of shark such as dog fish (Squalus acanthias), Greenland shark (Somniosus microcephalus) and barking shark (Certrohinus maximus) have large fatty livers weighing up to 10-25% of the whole fish containing 60- 75% oil. But halibut, tuna, and whale have 1% liver having 4 to 25% oil with high vitamin A & D content. Depending on the oil content and vitamin A potency fish livers are generally classified in to three groups.

Low oil content - high vitamin A potency

High oil content - low vitamin A potency

High oil content - medium vitamin A potency

Squalene from shark liver oil

Liver oils of some deep-sea sharks mainly Centrophorus sp. It contains 85% – 90% unsaponifiable matter which contains the hydrocarbon squalene. Squalene and its hydrogenated product are used for several decades as base for cosmetic products. It also used as skin rejuvenating agent. It is mild on human skin and imparts softness without oily appearance. The demand of squalene by cosmetic and pharmaceutical industry is on increase. Realizing the importance, ICAR- CIFT has developed a method of extraction, isolation and purification of squalene from shark liver oil

Fish silage

The product of the process of preserving and storing wet biological material in a silo (a pit or airtight container) is called silage. Silage production is considered one of the best ways of

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with green forage, preserved either by added acid or by the anaerobic production of lactic acid

“ ” logous products of whole fish or parts of fish. Fish silage can be defined as a liquid product made from whole fish or parts of fish to which no other material has been added other than an acid and in which liquefaction of the fish mass is brought about by enzymes already present in the fish.

Proteins Compound from secondary raw material

Fish hydrolysates

Fish protein hydrolysate is a product prepared from proteins sourced from fish meat/fish processing by products via enzymatic or chemical process. Enzymatically produced hydrolysates are widely accepted which contain mixture of peptides of varying sizes and free amino acids. The process consists of chopping, mincing, cooking, cooling to the desired temperature, hydrolysis, sieving, pasteurizing the liquid, concentrating and vacuum drying or spray drying of the product. Enzymes like papain, nisin, trypsin, bromelein, pancreatin are used for hydrolysis of fish protein

Hydrolysates find application as milk replacer and food flavouring agents. The proximate composition of fish protein hydrolysate would vary with the raw material (head, bone, skin, viscera), type of process, type of drying, extent of hydrolysis and any other pre-treatment of raw material. Fish protein hydrolysate are proven to have specific health role other than the nutritional benefit. Protein hydrolysates or peptides present in the hydrolysate have demonstrated to have antioxidant, anti-obesity, immune modulation, anticoagulation, anti-microbial, anticancer and antihypertension etc.

Fish Gelatin

Fish skin and scales which constitutes about 30% and 5% of the total seafood processing discards, respectively are considered as the richest source for collagen and gelatin, which have wide applications in nutraceutical product development due to its biocompatibility, biodegradability, and bioactive properties like antioxidant, antimicrobial, antihypertensive. Skin of fish constitute nearly 3% of the total weight and is suitable for the extraction of gelatin. Bones and scales can also be processed into gelatin. The process involves alternate washing of skin with alkali and acid and extracting gelatin with hot water. Gelatin finds applications in pharmaceutical products as encapsulation and in food industry as gelling agent. Fish gelatin has better relea ’
aroma and flavor with less inherent off-flavor and off-odor than a commercial pork gelatin.

Fish collagen

Collagen is a structural protein having a characteristics triple helix structure. Collagen is insoluble in water and fibrous in nature. Approximate molecular weight of a collagen molecule is 300KDa. Collagen derived from fish is generally of Type I and Type III. Type I and Type III collagen are the building blocks for connective tissues, bones and skins. Collagen is not soluble in water. However, fish type I collagen is unique in its extremely high solubility in dilute acid compared to avian and mammalian collagen. The solubility of collagen is affected by the pH and NaCl concentration of the solution

Collagen and gelatin hydrolysates

Although collagen/gelatin has several functional properties, its bioactivity is lower due to its high molecular weight. Hydrolyzing will enhance the bioactivities of the collagen/gelatin. Collagen or gelatin hydrolysates are produced by controlled hydrolysis of collagen or gelatin. Acid, alkali, enzyme or heat may be used for hydrolysis. During hydrolysis the peptide bonds are broken down producing low molecular weight peptides. The molecular weight of hydrolysate is generally in the range of 5.0-25 kDa

Fish maws/ isinglass

The world isinglass is derived from the Dutch and German words, which have the meaning ,

air bladder of deepwater hake is most suitable for production of isinglass. In India air bladders of eel and catfishes are used for the production of isinglass. The air bladders are separated from fish and temporarily preserved in salt during transport. On reaching the shore they are split open, washed thoroughly, outer membrane is removed by scraping and then air dried. Cleaned, desalted, air dried and hardened swimming bladders (fish maws) are softened by immersing in chilled water for several hours. They are mechanically cut into small pieces and rolled or compressed between hollow iron rollers that are cooled by water and provided with scraper for the removal of any adhering dried material. The rolling process converts the isinglass into thin strips or sheets of 1/8 ¼” for the production of isinglass in powder form also. Isinglass dissolves readily in most dilute acids or alkalis, but is insoluble in alcohol. It is used as a clarifying agent for beverages like wine, beer, vinegar etc.

Fish enzymes

Fish visceral waste contains rich sources of enzymes, which have potential applications in different sector includes food, biomolecule extraction, descaling of fish, stain removal and pharmaceutical applications. It has been reported that fish visceral waste contains rich source of proteolytic enzymes namely, pepsin, trypsin, chymotrypsin and collagenases. Enzyme extracted from marine sources has found application in Fish curing and fermentation, hydrolysed products production, pigment extraction, wastewater treatment and meat tenderizing. These enzymes also used as a component of biosensor for rapid assessment of fish quality.

Hemoproteins and Carotenoproteins

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 and carotenoids are other classes of compounds found in the flesh and skin of fishes and in the exoskeleton of shellfish. Astaxanthin, a ketocarotenoid pigment naturally found in crustaceans and represent 74 and 98% of the total pigments. It has found wide application in food, feed, pharmaceutical and cosmetic products. It is also used as dietary supplement with very potent antioxidant effect for human health. In pharmaceutical, it is used for treatment of

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cholesterol.

Mineral compound from secondary raw material

Fish calcium

The recommended daily intake of calcium is 1000 mg for the adults, and 1300 mg for elderly women. Fish bones and scales are excellent source of calcium. Whole small fish or fish bone/scale can be used for calcium separation. The filleting frames of carps and other fishes can be used for extraction of calcium. The frames are washed and boiled to separate the adhering meat portions. It is washed again and treated with enzymes to remove the adhering connective tissue, washed, dried and powdered. Fish calcium is essentially dicalcium phosphate which has better nutritional qualities. The hydrolysis of collagen or gelatin yields bioactive peptides that have great potential in processing industries as natural preservatives. Collagen and gelatin peptides are known to have excellent antioxidant properties unlike its parent molecules. Recently gelatin hydrolysate has been explored as plastisizer in protein film, identified as antihypertensive, cryoprotectant in additions to its wide known antioxidant activity.

Hydroxyapatite

The hydroxyapatite extracted from the scale are having uses as bioceramic coatings and bone fillers. The coatings of hydroxyapatite are often applied to metallic implants to alter the surface properties so as to avoid rejection by the body. Similarly, hydroxyapatite can be employed in forms such as powders, porous blocks or beads to fill bone defects or voids. For permanent filling of teeth hydroxyapatite is found to be a better option for import substitution.

Polymer compound from secondary raw material

Chitin

Chitin 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. 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.

Chitosan

Chitosan is prepared by deacetylation of chitin. The deacetylation is done by heating at 90-95°C with 40% (w/w) caustic soda for 90-120 min. The water present in the chitin cake should also be taken in to account while preparing caustic soda solution. To achieve this 50% caustic soda is prepared and calculated quantity of it is added to the chitin cake. The reaction is followed by testing the solubility of the residue in 1% acetic acid. As soon as the dissolution is completed caustic soda is removed from the reaction mixture. The drained caustic soda can be reused for the next batch of deacetylation by fortification if necessary. The residue is washed with water free of alkali. It is then centrifuged and dried in the sun or an artificial drier at a temperature not exceeding 80°C and pulverized to coarse particles.

Chitosan finds extensive applications in following areas viz; food industries, pharmaceutical applications, chemical industries, dental and surgical uses as a haemostatic agent, wound healing, biodegradable films as a substitute for artificial skins for removing toxic heavy metals, wine clarification, Industrial effluent treatment, agriculture, photography, cosmetic applications and textiles, and in nano applications

Glucosamine hydrochloride

Chitin can be hydrolysed to glucosamine hydrochloride by adding concentrated hydrochloric acid and warming until the solution no longer gives opalescence and diluting with water. The excess acid can be distilled off under vacuum. The crude glucosamine hydrochloride is diluted with water and clarified with activated charcoal. The solution is filtered and evaporated under vacuum. The crude glucosamine hydrochloride can be separated by adding alcohol.

Chitosan derivatives

Chitosan is not soluble in water but is soluble in dilute acid solutions like 1 % acetic acid. This has limited its applications in water soluble environments like human health and plant protection. Hence, the free amino and hydroxyl groups can be derivatized with new molecules to improve the functional properties of Chitosan. Advantages of Chitosan derivatives includes They are biodegradable and biocompatible; They are non-toxic and water soluble; They can be modified to impart special properties. Examples for chitosan derivatives are **N**-Trimethylene chloride Chitosan (TMC), Esters of chitosan with glutamate, succinate and phthalate Carboxymethyl chitosan (CM-Chitosan).

Major Applications of Chitosan derivatives includes 1) Controlled release and drug delivery 2) Scaffolds for biomedical applications like stents, organs 3) Tissue engineering, wound healing and regenerative medicine 4) Food supplements and natural preservatives 5) Anti-viral and anti-tumor applications 6) Bio-composite materials with functional properties

CIFT has developed technology for production of chitin, chitosan, glucosamine hydrochloride and carboxymethyl chitosan from prawn shell waste.

Other High value product from secondary raw material

Pearl essence

Pearl essence is the suspension of crystalline guanine in water or organic solvent. Guanine is an iridescent material found in the epidermal layers and scales of most pelagic species of fish like oil sardine, mackerel, herring etc. When guanine particles are deposited on the inside surface of solid beads, an optical effect similar to that of real pearl is obtained. It is used in the manufacture of artificial pearls. It is also used on diverse articles such as shoe, pencil, fishing rod and spectacle frame

Shark cartilage

The skeleton of shark is made of cartilaginous bones, which is about 10-15% of the body weight. Until recently, only very small quantity of these bones was made use of, that too from the small shark, for making buttons and necklaces. This cartilage is rich in chondroitin sulphate which has got application in medicine for treatment of atherosclerosis, blood vessel thrombosis and also to prevent infections. Now there is very good demand from Europe, USA and Australia for processed shark bones. The collected head and vertebral column of the shark are to be processed to a presentable and stable form before export. A procedure has been developed for the processing of the cartilage into a clean, dry, white, attractive material without any characteristic smell. The products are well accepted by the overseas buyers. The ban on shark fisheries is going to affect all these products, as mentioned above.

Shark fin rays

Shark fin rays are valuable products of export from India. Formerly, only shark fins were being exported. But now, fin rays are extracted and exported. CIFT has developed a technique for extracting rays from shark fins. The dried fins are soaked in dilute acetic acid for sufficient time to get the muscle and skin softened. The skin is then scraped off and the fins further treated with the dilute acetic acid when separation of the rays in clusters becomes easy. The rays are then dried and packed in polyethylene bags. The rays are utilised in the preparation of soup in many foreign countries. There is good internal demand also for shark fin rays especially in major star hotels.

Shark leather

Skin from both demersal as well as pelagic fish varieties are suitable for the leather production. Skins of shark can be processed into fine leather suitable for manufacture of fancy items. Leather tanned from Indian shark skin is about one and half times superior to that from cow hides in strength and durability. Shark skin has a protective coating of a calcareous deposit known as " " I used as a suitable raw material for manufacture of suitcases, shoes, belts, bags etc.

Conclusion

Seafood waste is prone to faster spoilage since it contains easily digestible protein and enzymes. The microbial population associated with the digestive process are the major reasons of spoilage. Accumulation of fishery waste results in nauseating and obnoxious smell due to the release of volatile nitrogenous compounds during decomposition. Hence utilization of seafood waste and development of high value product has high potential in recent years. A variety of by products can be developed which is found to have different applications in medical, food, and other fields. By simple cost-effective techniques, valuable products can be developed which will enhance the revenue of the fishermen and allied industries. In fact, the materials which caused problems to the fish processing industry due to the environmental pollution has become raw materials for valuable products with versatile application

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Protein and protein derivatives from aquatic food processing waste

Elavarasan, K.

By-Products Section, Fishing Processing Division, ICAR- CIFT, Cochin

elafishes@gmail.com

Introduction

I ’ ario, a large portion of the global population very much aware of health benefits one can achieve through consumption of aquatic food products. Particularly, fish and shellfish are highly nutritious and delicious. The demand for fish is ever increasing. On the other hand, aquatic animals like fish and shellfish are highly perishable compared to meat from land animals due to near neutral post mortem pH, low glycogen reservoir, low connective tissue content and high moisture content. Immediately after harvesting of fish (immediately after death), it undergoes various bio-chemical and microbiological changes which lead to spoilage. Hence, fish is essentially processed and preserved to make the fish available in edible condition. As a result of processing, a greater portion of raw material is discarded as waste which is biochemically equivalent to edible portion. In this chapter, the potentiality of fish waste as secondary raw materials, protein richness, waste generation during industrial processing and technology availability in producing protein and derivatives with ICAR-Central Institute of Fisheries Technology (ICAR-CIFT, Cochin) is briefed.

Secondary raw material

Aquatic food processing discards are now called as secondary raw material because of their potential for the production of high value products. For any country, to develop a systematic way to utilize or to set up an industry, the information on amount of waste generated would be the first aspect to be searched. Unfortunately, even in well developed countries, the data on waste generation from fish processing sector is not available, due to the complexity in obtaining such information. The available data are derived from the information on export quantity. However, it is essential to have information part wise, as many of the high value ingredients are derived from the specific parts (organs). The properties of derived high value products depend on the parts from which they are derived. For example, the properties of gelatin from fish skin, scale and bone are different.

Factors influencing the amount of waste generated

Fish processing sector generate two types of waste i.e. solid waste and liquid waste. Often the effluents undergo various treatments prior to discharging. Most often, the environmental issues are emerging when these discards are not properly handled/disposed particularly the solid waste creates the problem. The amount of waste generated from fish and shellfish depends on certain inherent aspects and processing related *parameters.*

Fish related parameters

- ✓ Species
- ✓ Size/Age group
- ✓ Biological nature (size of head, length of intestine, shorter fins etc.,)
- ✓ Body shape (Cylindrical, flat etc)

Process related parameters

- ✓ Style of dressing
- ✓ Style of product
- ✓ Skill of handling person
- ✓ Skill on handling the machines involved and their design
- ✓ Intended use
- ✓ Quality of raw material

Obtaining the information on waste generation is quite difficult with reference to above parameters. Hence, generating a data base for the commercially important processed fish is essential and highly useful for any nation which aims in industrial development in this sector.

Quantification of Secondary raw material of aquatic origin from India – A case study

During the financial year 2015-16, India has exported 9,45,892 MT of Seafood worth US$ 4.7 Billion (Rs. 30,420.83 crores). The quantity of export is roughly less than 1% of Indian total fish production. Today, the Indian seafood are tasted in 106 countries in the world and major markets are SE Asia, EU, USA, Japan, China and Middle East. India secured the position as a largest exporter of shrimp to USA, the 2nd largest exporter of shrimps to Europe and the 4th largest exporter of shrimps to Japan. The demand for Indian seafood products across the global consumers is increasing and the phase of Indian seafood business changes day by day. The resource and infrastructure of the Indian seafood industry has witnessed a tremendous growth in the recent past. India has an installed processing capacity of 23,000 M.T with 506 state-of-the-art processing plants, out of which over 62% of them are EU approved plants. Almost every plant has put in place HACCP and other Quality control system on par with the best in the world to ensure highest quality output.

Table 1. Amount of waste generated (%) during industrial processing of seafood

Products	Waste Generated (%; 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

In the present article, for estimating the approximate raw material could have been used and waste could have been generated in the processing industry, the waste percentage was considered conservatively. The presented value of waste generation is only from industrial processing sector and excluded the waste generation during house hold preparations. Hence the countries estimate for the fish by product generation will be definitely pretty higher than the represented figure.

Table 2. Approximate estimation of fish by products generated in the processing industry

Product	Quantity (ton)	Approximated waste percentage	Raw material quantity (ton)[1]	Quantity of waste generated (ton)[2]
Frozen shrimp	373866	40%	623110	249244
Frozen fin fish	228749	50%	457498	228749
Frozen cuttlefish	65596	50%	131192	65596
frozen squid	81769	50%	163538	81769
Dried items	43320	20%	54150	10830
Live items	5493	00%	5493	0
Chilled items	33150	20%	41437.5	8287.5
Others	113949	10%	126610	12661
Total	945892		1603028.5	657136.5

[1, 2]The presented values are approximate estimation, not the actual figures.

Protein content in secondary raw material

The discards from fish/shellfish contain protein in the range of 9-27% depends on the waste parts. The tissue proteins for example the meat from head and filleting frames contains major muscle protein fractions like myosin, actin, troponin, tropomyosin etc. The skin, scale and bone contains the protein namely collagen (an integral protein moiety of connective tissues). Shrimp shell waste contains carotenoproteins.

Table 3. Categorization of seafood discards

Based on the site	Based on physical state of waste		Based on the aquatic animal	Based on the richness of bio-chemical constituent	Based on the complexity
	Solid waste	**Liquid waste (effluents)**			
• On board waste • Industrial waste • Landing center waste • Retail waste • Waste from domestic preparation	• Dark meat • Head • Skin • Scale • Fins • Frames • Visceral mass (including Air bladder and liver) • Gills • Crab shells • Shrimp head and shells • Cuttle fish bone • Squid pen • Ink sac • Cuttle fish skin • Shells from oyster, mussels and clams	• Effluents consist of blood, slime, mucus, wash off (Processing units effluents and peeling shed effluents) • Surimi wash water	• Fin fish waste • Shellfish waste • Crustacean waste • Cephalopods waste • Mollusk waste	• Waste rich in protein • Waste rich in lipid • Waste rich in minerals • Waste with special molecules	• Simple waste (Scale, skin, shrimp cuticle) • Complex waste (Head waste, visceral waste, shrimp head, Squid and cuttlefish waste)

Table 4. Protein content in major fish waste parts

	Waste Parts	Protein (%)
1.	Head	11-13
2.	Back-bone/ frame	10-15
3.	Cut-offs	12-22
4.	Skin	8-12
5.	Milt	14-27
6.	Viscera	9-23
7.	Shrimp head waste	9-14%

(Source: Rustard, 2007**)**

Handling of secondary raw material

Considering the importance of secondary raw material generated in seafood processing industry, the hygienic handling of raw material to be given due importance. Without proper utilization of secondary raw material, sustainability in fish processing sector will be impossible. The following points may be followed to maintain the quality based on the intended use.

- Collection of waste
- Sorting of waste parts wise and based on quality
- Washing in chilled water/chlorinated water
- Packing in a suitable packaging material
- Preservation based on the intended use (Chilling, freezing, salting and drying or any other chemical treatment)

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 protei I 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% ’ -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 ’ -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).

Protein derivatives from secondary raw material

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.

Application of fish protein hydrolysates

Nutritional application

The proximate composition of fish protein hydrolysate would vary with the raw material (head, bone, skin, viscera), type of process, type of drying, extent of hydrolysis and any other pre-treatment of raw material. The chemical composition of food materials has an important role on human health in supply of essential nutrients for maintaining prosperous health. Chemical composition of fish protein hydrolysates is important in nutrition perspective of human health.

Table 6. Proximate composition of fish protein hydrolysate

Waste Parts	Protein (%)
Moisture	< 10 %
Protein	60-90 %
Fat	<5 %
Ash	0.45-27%

(Source; Chalamaiah et al., 2010)

Amino acid composition of protein hydrolysates from different raw material produced using different enzyme source under different hydrolysis conditions expected to have variation. In general, required essential amino acids are abundant in FPH with richness in glutamic and aspartic acid content. FPH do also have non-essential amino acids. Presence of aromatic amino acid in fish frame protein hydrolysates has been reported. Studies have clearly shown that FPH from fish meat/fish waste could be an ideal source of essential amino acids (Chalamaiah et al., 2010).

Nutraceutical applications

There are fish protein hydrolysate products/peptides specifically marketed as health supplements in developed countries. These products are proven to have specific health role other than the nutritional benefit. Protein hyd5rolysates or peptides present in the hydrolysate have demonstrated to have antioxidant, anti-obesity, immune modulation, anti-coagulation, anti-microbial, anticancer and antihypertension etc. (Elavarasan et al., 2014; and Elavarasan et al., 2016).

Table 7. Commercially marketed fish protein hdyrolysate products as Nutraceuticals

Product brand name	Particulars	Nutraceutical applications	Country
PROTIZEN®	Produced by enzymatic hydrolysis of white fish proteins	I “ ” supplement to fight against stress and its symptoms (weight disorders<comma> work pressure<comma> sleep troubles<comma> concentration difficulties and mood troubles).	UK
Amizate®	Produced from Atlantic salmon fish proteins by autolysis	(’ muscle anabolism and metabolic recovery).	North America
Nutripeptin®	Manufactured by enzymatic hydrolysis of Cod fish fillet/muscle protein	It helps in the blood glucose stabilization<comma> and weight management.	UK and USA
Seacure®	Prepared by hydrolyzing deep ocean white fish proteins	Dietary supplement helps to support the cells in the gastrointestinal tract and regulate bowel functions.	US and Canada
Vasotensin®	Produced from Bonito (*Sarda orientalis*) by thermolysin hydrolysis	It supports healthy vascular function for optimal blood flow and healthy blood pressure levels.	US and Japan
LIQUAMEN®	Prepared from *Molva molva* by autolysis	Dietary supplement that helps in reducing oxidative stress<comma> lowering glycemic index and anti-stress.	UK
Stabilium® 200	Prepared from *Molva dypterygia* by autolysis	’ stress and provides nutritional support for memory and cognitive function.	UK
PEPTACE®	Produced from Bonito (*Sarda orientalis*) by thermolysin hydrolysis	It lowers the blood pressure by inhibiting ACE enzyme.	US and Japan
SEAGEST®	Prepared by hydrolyzing deep	It supports the structure of the intestinal lining and promotes intestinal health.	US

	ocean white fish proteins		
MOLVAL®	Produced from North Atlantic fish *Molva molva* by enzymatic hydrolysis	Dietary supplement recommended for cholesterol equilibrium<comma> stress control and promotes good cardiovascular health.	UK

(Source: Chalamaiah et al., 2010)

Fish protein hydrolysate as a functional ingredient

Fish protein hydrolysates are soluble in wide range of pH which is an ideal characteristic helps to use in wide range of products. Protein hydrolysates have improved water holding, oil binding, emulsifying and foaming properties. However, the key factor which determine the functional properties is degree of hydrolysis. In general, extensive hydrolysis leads to loss of functionality. There is a critical degree of hydrolysis at which protein hydrolysates should be prepared with reference to particular function to be used as a functional ingredient (Elavarasan et al., 2016; Gajanan et al., 2017).

Fish protein hydrolysate as a feed ingredient and other applications

Fish protein hydrolysates (FPHs) have been used in aquaculture feeds in order to enhance the growth and survival of fish. Studies have shown that FPH has boosted the growth performance and immunological status of many culture species. The amino acid composition and the peptides present in hydrolysate are responsible for the improved growth and immunological status. FPH is also being used as a source of protein in poultry feed formulation and in pet animal foods. Other applications include FPH as a plant booster, ingredient in microbiological media and as a cryo-protectant in fish mince/surimi.

Collagen peptide/gelatin hydrolysate

‘ ’, ‘ ’ ‘ ’ are high molecular weight proteins of approximately 300 kDa, it is difficult for digestion and hence becomes unavailable to human body for their biological functions. Consequently, in recent years, much attention has been paid to the development of small molecular weight peptides from the native collagen with improved biological activities. This can be achieved by the process of hydrolysis in which the native collagen/gelatin molecules are cleaved to small fragments. The hydrolysis process leads to formation of fragmenting from the collagen of about 300 kDa to small peptides having an average molecular weight of less than 5 kDa. The visible consequence of this hydrolytic transformation is the complete dissolution of resultant peptide mixture in cold water, which further widens the application prospects of collagen peptide.

Small peptides are desirable for nutraceutical and pharmaceutical applications, whereas large peptides are desirable for the functional modification of food products. Standardisation of collagen production technology is a stepping stone in the nutraceutical and health food industry. From a nutritional perspective, peptides are more bioavailable than proteins or free amino acids and at the same time, less allergenic than their native proteins (Otani et al., 1990). Apart from that collagen peptides are shown to promote the absorption of vitamins and minerals. Hence, recently combined formulations of collagen peptide with minerals and vitamins are coming up in the market. Apart from their nutritional benefits, bioactive collagen peptides possess a wide range of physiological functions including antihypertensive, antioxidative, anticancer, immunomodulatory, antimicrobial, mineral binding, antithrombotic and hypocholesterolemic effects (Gomez-Guillen et al., 2011). Enzymatically hydrolyzed collagen have shown better biological activities compared to the peptides derived from fish muscle protein with antioxidants and antihypertensive agents.

Table 8. The protein derivatives from secondary raw material and the possible industrial products

Protein derivatives from secondary raw material	**Protein derivatives based industrial products from secondary raw material**
• Fish protein hydrolysate • Collagen peptides • Gelatin hydrolysate	• Fish silage • Flavorings • Collagen peptides • Gelatin hydrolysate • Fish protein hydrolysate • Shrimp protein hydrolysate • Fish waste paste • Cuttlefish and squid by-products paste

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 protein based product from fish waste is collagen and its derivatives. The way the fish waste utilized in India needs a rattled shift in order to realize the full potential of seafood processing waste generated in India.

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Marine Nutraceuticals from seafood waste

Binsi P. K
Scientist
Fishing Processing Division, ICAR- CIFT, Cochin

Introduction

The marine ecosystem is still an underexploited reservoir of several bioactive compounds, having significant therapeutic and prophylactic role against a number of common lifestyle diseases. With the growing public consciousness of the health benefits of fish and seafood in general, the health food platform is now to set for the development of mainstream nutraceutical formulations. The current nutraceutical industry is familiar with a small number of marine-based nutraceuticals. Fish oil (mainly omega-3 polyunsaturated fatty acids), algal oil, shark liver oil and squalene, chondroitin salts, collagen, gelatin, collagen peptide, chitin, chitosan as well as their monomers and oligomers, peptides and related compounds, vitamins (A, particularly its precursor β-carotene, D and E), seaweed (macroalgae) and its components, protein hydrolysates and other products have become a topic of great interest for both pharmaceutical and health food industries.

It is estimated that fish processing waste after filleting accounts for approximately 75% of the total fish weight. About 30% of the total fish weight remains as waste in the form of skins and bones during preparation of fish fillets. Bio conversion of these wastes is an environmental friendly and profitable option for the utilisation of fish waste. Some viable options for generating wealth from waste through nutraceutical products are discussed in this chapter.

Options and opportunities

Generally two different methods, mass transformation and sorting, have been developed to improve the economic value of fish wastes. Mass transformation involves the conversion of fish waste into a single product. Typical examples of transformed fish waste include fishmeal, fish oil, fertilisers, and hydrolysates such as protein hydrolysate. Alternatively, sorting involves utilising various fish body parts such as bones, guts, and fins separately to enhance their economic value. For example, sorting enables the production of specialised products such as liver oil, gelatine, omega-3, protein containing sports food and drinks, calcium, cosmetics, and pharmaceuticals. Wider acceptance and adoption of both methods could lead to significant reductions in wastes going to landfill and reduce the damaging impact of fish wastes on the environment.

***Fish protein hydrolysate*:** Fish protein hydrolysates are obtained by the controlled hydrolysis of fish protein either by employing acid, alkali or commercially available proteolytic enzymes. Hydrolysates find application as milk replace and food flavouring. Enzymes like papain, ficin, trypsin, bromelein and pancreatin are used for hydrolysis. The process consists of chopping, mincing, cooking and cooling to the desired temperature, hydrolysis, sieving, pasteurizing the liquid, concentrating and drying (by vacuum or spray drying). The fish protein hydrolysate have desirable functional properties with potential applications as emulsifiers and binder agents; and can be used in place of diary based and plant based protein hydrolysates as well as protein powders currently available in market place (Binsi et al., 2016). The yield of hydrolysate is a critical parameter which decides the economics of operation. The yield is primarily dependent on factors such as enzyme-substrate ratio, temperature, ph, hydrolysis period, enzyme used etc.

The peptides formed by the hydrolysis of fish proteins are proven to have bioactive properties like antihypertensive, antithrombotic, immune modulatory and antioxidative properties. Also, they are good source of nutritional and functional properties. A variety of nutraceuticals from FPH are commercially produced and are available in international markets. Oyster peptide extract developed by ICAR-CIFT possessed antioxidant and anti-inflammatory activities. Similarly, hydrolysate made from squilla meat effectively reduced oil absorption in breaded and battered products, when incorporated in the batter mix.

In the industrial process of preparation of hydrolysates enzyme hydrolysis process is followed. Papain, bromelein, pepsin, ficin and trypsin are used for hydrolysis. Most hydrolysates are bitter in taste. Hence flavouring agents are like cocoa, malt and sugar are used during the fortification in food preparation to mask the bitter taste. Protein hydrolysate has special application in sports medicine because its consumption allows amino acids to be absorbed by the body more rapidly than intact proteins, thus maximizing nutrient delivery to muscle tissues. Bioactive peptides are generally short peptides (3–20 amino acids) derived from proteins that can exert biological activities over and above their expected nutritional value. From a nutritional perspective, these peptides are more bioavailable than proteins or free amino acids and at the same time, less allergenic than their native proteins. Apart from their nutritional benefits, bioactive peptides exhibit a wide range of physiological functions including antihypertensive, antioxidative, opioid agonistic, anticancer immunomodulatory, antiproliferative, antimicrobial, prebiotic, mineral binding, antithrombotic, hypolipidemic and hypocholesterolemic effects. These beneficial properties of fish protein hydrolysates may be due to the unique combination or high proportions of certain amino acids such as arginine and taurine with low levels of branched-chain amino acids found in fish meat.

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

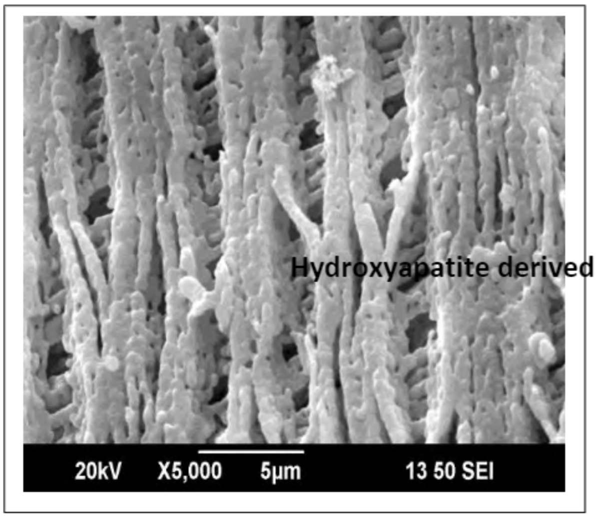
Collagen peptide from fish scale and Nutritional mix formulated by CIFT

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

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

Calcium extracted from Tuna bone

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



Hydroxyapatite derived from fish scale

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

Taurine: Taurine is a sulfur-containing non-protein amino acid (2-aminoethanesulfonic acid), with multiple functions like neurotransmission, cell volume regulation, stabilization of cell membranes and in the transport of ions such as calcium, sodium, potassium and magnesium. Taurine is one of the most abundant amino acids in the brain, retina, muscle tissue, and organs throughout the body, and taurine deficiency is associated with cardiomyopathy, retinal and tapetum degeneration, renal dysfunction, immune deficiency, muscle atrophy, developmental abnormalities, premature aging, and impaired reproduction. It can be synthesized from methionine and cysteine with the help of vit B6. The importance of taurine in biological system

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function, and cholesterol metabolism. The osmoregulatory role of taurine in facilitating the passage of sodium, potassium, calcium and magnesium ions into and out of cells, thereby stabilizing the structural and functional integrity of cell membranes was well discussed in earlier reports. It is involved in detoxification of xenobiotics and also essentially required for efficient fat absorption and solubilisation. Taurine has a protective effect on the tissue damage that results from oxygen free radicals in mercury induced toxicity. It plays a crucial role in prenatal and infant development. Epidemiological studies have shown that increased taurine intake is associated with diminished risk of hypertension. The deficiency of taurine does not impose immediate health issues, however long-term deprivation can affect a multitude of metabolic pathways. It is a key ingredient of bile and has a major role in the maintenance of normal gastrointestinal development and functions. Taurine is found in greater concentrations in all animal products. Meat, breast milk, dairy products, and fish are good sources of taurine. Shell fish contain higher concentration of taurine compared to that of fin fish. Zhao et al. (1998) determined the taurine concentration of a variety of common marine fish species and reported the highest content in crustacean and molluscs, ranging from 300-800 mg per 100 g meat. Apart from that red algae is considered as a good edible source of taurine. A possible beneficial action of taurine P ’ H ’ x

apoptosis is proposed. Eventhough, the cellular and biochemical mechanisms mediating the actions of taurine are not fully revealed, mounting evidences suggest that taurine might be a key functional ingredient for use as a nutritional supplement to protect against oxidative stress, neurodegenerative diseases, atherosclerosis and hypertension.

Glucosaminoglycans: Glucosaminoglycans (GAGs) are linear polysaccharides with repeating sequences of disaccharides consisting of an amino sugar (*N*-acetylglucosamine, or *N*-acetylgalactosamine) and uronic acid (glucuronic acid or iduronic acid) or galactose. The major members of GAGs are hyaluronic acid or hyaluronan (HA), keratin sulfate (KS), chondroitin (CS), dermatan sulfate (DS), heparin and heparin sulfate (HS). HA is a high molecular weight molecule, typically with 2 -10 x 10^7 Da and 2–25 μ , , short-chain molecules with of less than 50 kDa, more commonly 15–20 kDa. Hyaluronan lacks sulfate groups and is not covalently linked to protein, but the rest of the glycosaminoglycans are covalently linked to a protein core and contain sulfates at various positions. Dermatan sulphate is distinguished from chondroitin sulfate by the presence of iduronic acid. Keratan sulfates contains sulfated galactose and *N*-acetylglucosamine in place of uronic acids. GAGs are primarily considered as the components of various structural and connective tissues. Apart from the structural role, GAGs have been found to be associated with the regulation of a number of proteins, including chemokines, cytokines, defensins, growth factors, enzymes, proteins of the complement system and adhesion molecules. Apart from that, a few members like heparin possess anticoagulant, and anti-inflammatory properties. Dermatan sulfate (chondroitin sulfate B), also has a range of biological properties, although it has not yet been considered for therapeutic purposes. Marine heparin extracted from shrimp and sea squirt has proven anti-inflammatory properties.

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

Melanin : Cephalopods comprising mainly squids and cuttlefishes form an important resource of world oceans and their economic importance is growing exponentially. Consequently, cephalopods have emerged in recent years as an important component of the marine products, and are considered as a major delicacy in export markets. While several products (fillets, tubes, rings etc.) are made from cuttlefish, squid and octopus, considerable quantity, including the ink sac is disposed as waste. Interestingly, the cephalopod ink was identified as the most useful resource for the commercially important pigment melanin. Basically, squid ink is an intermixture of melanin, proteins, lipids, carbohydrates, glycosaminoglycans, various minerals etc. The predominant components are melanin and protein-polysaccharides complex. Each ink sac of sepia has ~1 g of melanin, and melanin constitutes ~15% of the total wet weight of ink with other proteins.

The basic structure of melanin comprises of covalently linked indole structure (Takaya and others 1994). Melanin performs a number of biological functions in the body, the main function being to protect the organism from harmful agents such as ultraviolet (UV) radiation; melanin is capable of dissipating over 99% of absorbed UV light. Besides, in the biological system, melanin plays a vital role in providing mechanical strength and protecting proteins from degradation. Numerous reports published in last thirty years reveal the therapeutic, prophylactic and curative value of cephalopod ink. The anti-ulcerogeneic properties and anti-

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Mimura et al. through a series of rat model studies. Later on, several researchers confirmed the effect of squid melanin on both phenylbutazone induced ulceration in gastric mucosa and secretion of gastric juice in rats. Apart from that, melanin has been reported to have radio-protective activity, antitumor activity, immunomodulatory activity, procoagulant function and so on. Natural melanin has been reported to have defense activity, protection function and metal chelating ability. It could participate in physiological and pathological activities in human body and even in the treatment of Acquired Immune Deficiency Syndrome (AIDS). A new generation photo-thermal dopamine-melanin colloidal nanospheres was developed by Liu et al. (2012) which could efficiently damage tumour cells at low power density and short duration, without damaging healthy tissues. Melanin also functions as photoprotective and chemoprotective pigment, protecting the body from damaging radiations, as observed at an effective dose of 50 mg/kg body weight in mice model. Similarly, oral administration of melanin for protection against radiation was reported by Dadachova et al (2016). The protective activity of melanin is primarily attributed to the inhibition of radiation-induced hematopoietic damages. Several other physiological studies conducted on squid ink also revealed significant effects on granulopoiesis of hemopoiesis impaired mice induced by ^{60} γ cyclophosphamide, but has no effect on erythropoiesis. Melanin has been widely and conventionally used as an antioxidant and natural colorant in food formulation.The most interesting thing is that melanin can be used as food additives to prevent the rancidity caused by the presence of bacteria by quenching the bacterial quorum sensing. Squid melanin was reported to have hemopoietic function in Iron Deficiency Anaemic rats, which might be exploited as a safe, efficient new iron tonic. Deficiency of melanin is associated with disorders such as vitiligo and oculocutaneous albinism. Interestingly, melanin is thought to play a protective role against the age-associated and noice-induced hearing loss. Recently, the anti-ageing property of melanin was demonstrated in mice model, suggesting its use in neutracosmetic formulations. Eventhough melanin is a part of normal human diet, research on dietary intake of melanin is not much explored.

Melanin from cuttlefish ink

Marine algae

Algae, in particular, are virtually fat and calorie-free, making them increasingly sought for commercial purposes. Macroalgae, ***generally referred as seaweeds***, have been found to be good sources of dietary fiber and carotenoids with antioxidant activity and play important roles in the prevention of neurodegenerative diseases. Several bioactive compounds have been isolated from brown algae with different pharmacological activities such as cytotoxic, antitumor, nematocidal, antifungal, anti-inflammatory and antioxidant. Algins, carrageenans and agar are examples of polysaccharides derived from algae that are widely used as thickeners and stabilizers in foods as well as for gels. Sulphated fucans, carrageenans and ulvans, have been known to act as modulators of coagulation as well as reveal antithrombotic, anti-inflammatory, antioxidant, anticancer and antidiabetic activities, among. Soluble polysaccharides from algae have tremendous potential as dietary fiber for human nutrition and are being evaluated as new possible prebiotic compounds. Microalgae are considered important producers of some highly bioactive compounds found in marine resources; they can be used to improve food nutritional profile due to their richness in PUFAs and pigments such as carotenoids and chlorophylls.

Challenges and way backwards

The key to successful seafood waste utilisation and management is to develop appropriate eco-friendly reprocessing technologies that can convert all the valuable components present in the waste into valuable products and reduce the amount of waste going to disposal route. However, there are many challenges that must be overcome to achieve this goal.

1. Consumer awareness and education is one such challenge. Without consumer acceptance of food waste reduction approaches, no sustainable eco-friendly food waste utilisation and management strategy can succeed. This demands proper extension efforts from the research and extension organizations.

2. Seafood sector is a poorly organised sector. Highly scattered nature of seafood processing operations (across domestic market and processing acilities) poses problems in collection and processing.

3. Seafoods are highly perishable in nature owing to its unique richness in terms of protein, peptides, enzymes and microbial flora. This quite often leads to the mass resistance from public in starting up a business venture in the vicinity.

4. Stringent legal and environmental restrictions from the regulatory bodies as seafood waste “ / ” j invest upon this resource

5. Inappropriate cold chain management from the source of generation to the point of conversion as the processors are least interested to invest further on discards

6. There is no baseline data on the availability and economics of production collected over the past years, which poses uncertainty about economics and market demand of secondary products
7. Lack of clear legal classification of secondary products in the international market is yet another major challenge to the investors
8. Lack of unified protocols for quality assurance (such as HACCP) for secondary products leads to frequent rejections from the buyers.

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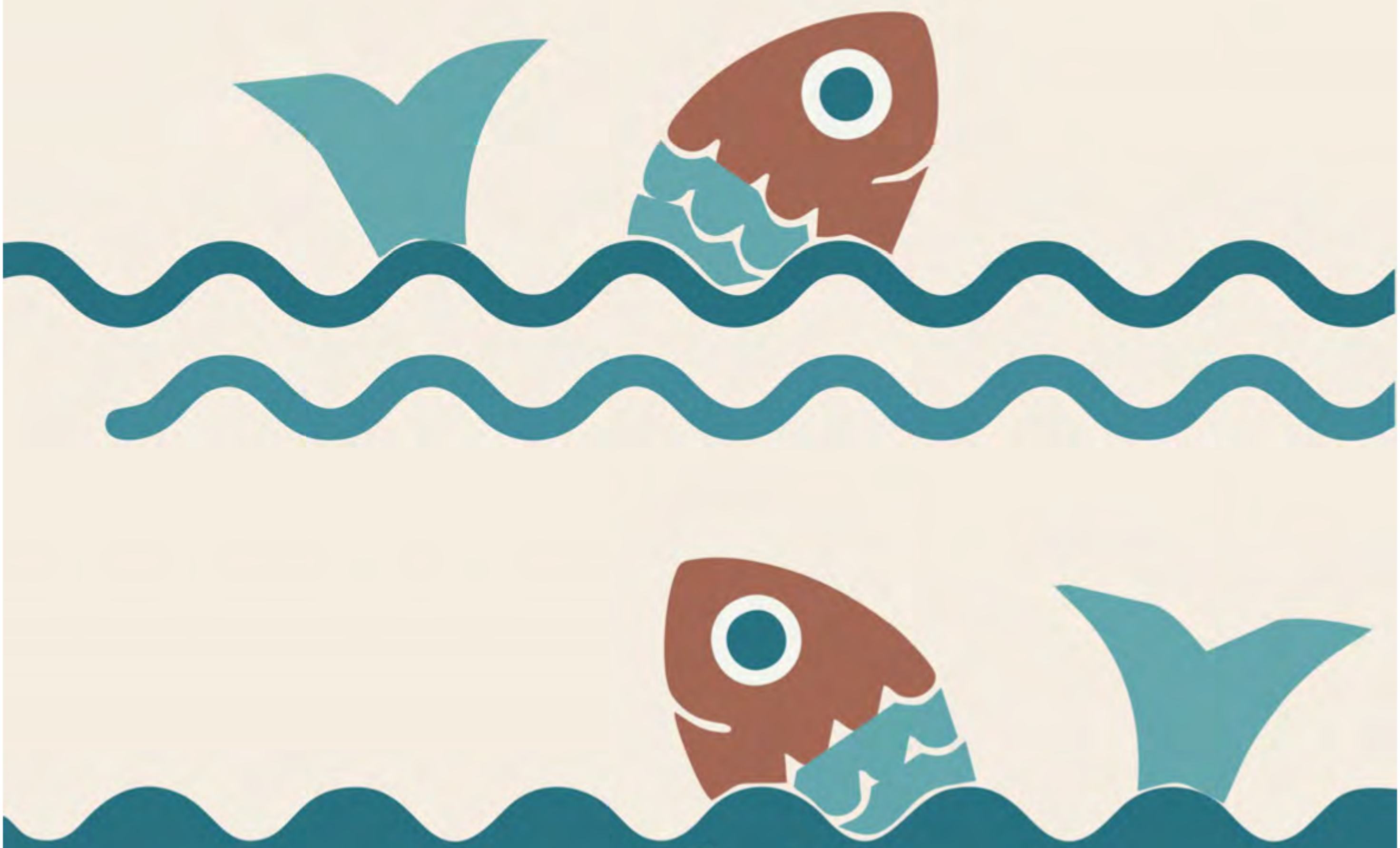

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