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This issue of FISHTECH Reporter comprises nine articles covering a range of topics aimed at strengthening sustainable harvest technologies to post-harvest technologies that maximize the utilization of fishery resources through value addition, modern processing methods, industrial, and biomedical applications. ICAR-Central Institute of Fisheries Technology (ICAR-CIFT) conceptualized the idea of developing fishing boats powered by non-polluting energy sources, viz., the solar energy and animate energy (energy derived from human muscle power, as in the case of pedal boats). The specifications of CIFT Sun Boat and CIFT Pedal Boat that were the outcomes of this initiative are detailed in the first article. The second article discusses about the underwater field study carried out by ICAR-CIFT on the social behaviours of Indo-Pacific bottlenose dolphins from Andaman waters. The next article discusses the abandonment of first-generation FRP boats along coastlines, particularly in Gujarat, which adds to the plastic-based marine litter resulting in habitat destruction or microplastic pollution. The articles also emphasized the role of ICAR-CIFT in not only addressing the problems, but also in facilitating sustainable solutions and promoting efficient fishing practices which will in turn ensure healthier marine ecosystems.

One of the main goals of fish processing technology is to develop new products and applications from seafood and secondary raw materials. Squid is a highly nutritious and versatile seafood that is gaining popularity as a healthy and economically valuable ingredient in the global food market. One of the articles elucidates the development of air-fried squid jerky that is flavourful, nutritious and shelf-stable product. This edition also highlights the use of microalgae gel beads as a convenient and palatable nutrient delivery system that can find applications in the food industry for the convenient delivery of microalgal nutrients and bioactive compounds. Another article explores the promising yet underutilized marine resource, myctophid fishes, *Neoscopelus microchir* and *Diaphus watasei*, with great potential in the field of nutraceuticals. A study was carried out to

From the EDITOR'S DESK

standardize dried clam with superior quality attributes suitable for storage and consumption. The article also details the use of IR dryer developed at ICAR-CIFT, Kochi for the drying of clams. A detailed study on the recovery method of the endophytic bacteria from *Ulva intestinalis*, a green seaweed is also included.

Lastly, one article on social sciences have been presented in this issue. The study examines different communication pathways that influence price dynamics in Kerala's marine fish markets, focusing on information asymmetry, market linkages and intermediary roles.

Fish processing technology is a dynamic and multidisciplinary field that offers many opportunities and benefits for the fish industry and consumers. However, it also requires careful evaluation and optimization of the processes and products to ensure their quality, safety, functionality, and environmental compatibility. I hope that the articles in this issue will stimulate further interest and research in this exciting area.

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Sailing towards sustainability: LCA insights for green boat designs by ICAR-CIFT for net-zero carbon fishing

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The annual fuel consumption rate of Indian fishing vessels has been estimated at 1.52 ton/ton of fish catch (Dineshababu et al., 2024). Equating with the total landing of 2024-25 (3.53 MMT), the equivalent carbon emission to the atmosphere would be 5.36 MMT. Globally, total CO₂ emissions have reached about 3 billion metric tons, out of which the fisheries sector contributes less than 1% (Crippa et al., 2024). The increasing fuel cost causes significant profit reduction of the fishing-related activities, and thus there is a need for renewable and non-polluting energy resources for boat propulsion (Baiju, 2019).

The ICAR-Central Institute of Fisheries Technology (ICAR-CIFT) conceptualized the idea of developing fishing boats powered by non-polluting energy sources, viz., the solar energy and animate energy (energy derived from human muscle power, as in the case of pedal boats). The CIFT Sun Boat and CIFT Pedal Boat were the outcomes of this initiative. Both these boats can be effectively operated for gill netting, line fishing, recreational fishing, and transportation, promoting the use of renewable energy in the small-scale inland fishing sector.

The solar boat is battery-operated, which can attain 5-6 knots of speed in calm water and is capable of running for 3 to 4 hours after complete charging. The detailed specifications of the boat are provided in Table 1. The FRP roof of the boat safeguards fishers during operations, shielding them from the sun and rain. The twin hull gives better stability during maneuvering and also facilitates a wider deck area. The navigational lights are battery-operated, which can be charged by solar power. The solar boat costs 2-2.5 times more than the traditional boat of the same LoA (length over all), since photovoltaic cells, battery bank and steering control system add to the cost. However, the additional investment can be recovered within 8 years for Sun boats and within 2 years for Pedal boats, assuming 240 fishing days per year and a service life of 25 years (Figure 1).

Unlike the marine sector, the extent of appropriate technological applications in the inland fishing sector is very low. Boats that are mainly used for recreational purposes are usually modified for fishing purposes as Pedal boat, which is another milestone towards the goal to improve the

harvest efficiency in reservoirs and achieving net zero emissions. FRP Pedal boat has zero operational energy utilization and zero carbon footprints, which is best suited for the small-scale gillnetting in reservoirs. Generally, the small-scale FRP boats are usually propelled by outboard motors that run on fossil fuel. However, the Pedal boat runs on animate energy which makes its operation clean and green. The designed pedal fishing boat has a length of 4 m, breadth 1 m and depth 0.6 m (Figure 2). It requires less maintenance, and there is no fuel required and hence zero pollution, which makes it a green and sustainable technology. Small-scale coastal gillnet fishing is generally performed by a single fisher, making it difficult to manoeuvre the boat and deploy the net simultaneously. Pedal boat is one of the best options for reservoir fishers, which addresses the issue of navigating the boat while deploying the gear without any fuel consumption. In both solar and pedal boats, the constructional inputs used were IRS-approved (Table 1).

After the successful operation of these boats in fish farms and inland water bodies of Kerala, the economic feasibility was worked out based on different indicators, and it was found that there was profit on investment from second year onwards (Table 2).

Table 1. Technical specifications of Pedal and Sun boat

| Parameters | Pedal boat | CIFT Sun Boat |
|-----------------------------------|------------|---|
| Length over all (LoA) (m) | 3.0 | 8.0 |
| Breadth extreme (m) | 0.92 | 2.4 |
| Breadth demi hull (m) | NA | 0.88 |
| Depth (m) | 0.35 | 0.75 |
| Draft (m) | 0.2 | 0.30 |
| Capacity (persons) | 2 | 8 |
| Solar panel nominal power (385 W) | NIL | 4 Nos |
| Material of construction | FRP | FRP |
| Electric OBM power (kW) | NA | 7.92 (20 HP Comparable Gas/Petrol Rating) |
| Battery | NA | Lead Acid Battery of Nominal Capacity: 225AH @ C20 (6V x 6 Nos). Also smart Solar Charge Controller of battery Voltage: 12/24/48V at rated charge current of 85A. |



Figure 1. Pedal boat and Sun boat

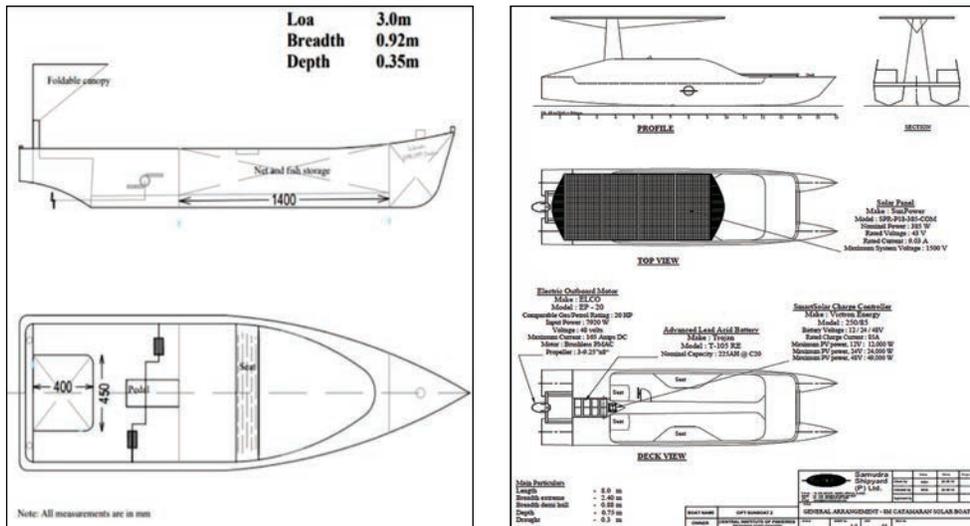


Figure 2. General arrangement drawing of Pedal boat and Sun boat

Table 2. Financial indicators of Pedal and Sun boat

| Item | Amount (Lakhs) | |
|---|---------------------|------------------|
| | Pedal boat (3.63 m) | Sun boat (8.0 m) |
| Cost of boat | 3.0 | 10.0 |
| Gear and accessories | 0.5 | 0.5 |
| Total Capital Investment | 3.5 | 10.5 |
| Interest on capital (@10%) | 0.35 | 1.05 |
| Depreciation (@15%) | 0.52 | 1.57 |
| Annual total fixed cost | 4.37 | 13.12 |
| Wages | 0.72 | 0.72 |
| Total operational cost | 0.72 | 0.72 |
| Total cost | 5.09 | 13.84 |
| Revenue from fish sale/tourism | 3.4 | 6.8 |
| Fuel saving | 3.72 | 7.5 |
| Total revenue | 7.12 | 14.3 |
| Annual Net Profit (from 1 st year) | 2.03 | 0.46 |

Fiber Reinforced Plastic (FRP) is an affordable alternative for conventional boat-building material, and it has more durability and life span compared to other boat-building materials. However, the major drawback associated with FRP is its high carbon footprint, whereas the fishing boat made of wood and steel claims less carbon footprint compared to FRP (Jha et al., 2021). There are several inputs which contribute to equivalent carbon emission (eq. CO₂) to the FRP fishing boat. In order to understand the contribution of various inventories to environmental deterioration, a Life Cycle Assessment (LCA) study was conducted for the boat

construction phase (cradle to gate approach). The life cycle of a product involves examining its processes and activities, starting from raw material extraction to manufacturing, distribution, usage, and, where applicable, recycling and waste treatment (ISO, 14044). SimaPro software (PRé Sustainability) was used for calculating eq. CO₂ emission. The IPCC 2013 GWP 100a V1.03 method was adopted for estimation of eq. CO₂ emission. The functional unit for the constructional carbon footprint was one unit of Pedal and Sun boat, whereas for the operational footprint, it was eq. CO₂ emission per boat per year with the fossil fuel-operated boat of similar length. It was evident from the results that in both cases, the epoxy resin and aluminum were the major contributors to eq. CO₂ emission. However, an assumption-based analysis was carried out based on the following criteria: 6 hours of fishing per day (2 hours of active cruising for reaching to fishing grounds and back, plus 4 hours of fishing gear operation with the engine idling); 240 fishing days per year; and a fuel consumption of 3 litres per day for one OBM. This analysis included boats similar to Pedal boat with one 9.9 hp OBM and boats similar to the Sun boat with two 9.9 hp OBM. With these assumptions, the total fuel consumption calculated would be around $240 \times 3 = 720$ litres for boats similar to Pedal boat and 1440 litres for boats similar to Sun boat. Converting this quantity of fuel utilised would be equivalent to 1663 kg of CO₂ eq./year for the Pedal boat and around 3326 kg of CO₂ eq./year for Sun boat (2.31 kg of CO₂ eq. were taken as the emission factor of petrol; Kumarakannan et al., 2019) (Figure 3 & 4). The estimation depicts that the constructional footprint of Pedal boat is about half of the operational footprint due to fossil fuel consumption per year. The operational footprint of the Sun boat is about 35% of the constructional footprint per year due to the burning of fossil fuel.

The construction of the Pedal boat accounts for a total carbon footprint of 829.8 kg CO₂ equivalent, while the Sun boat exhibits a much higher footprint of 4499 kg CO₂ equivalent. This more than fivefold increase suggests a larger vessel with a robust structure and more quantities of materials in the construction. In both cases, epoxy resin accounts for the most significant contributor to the overall carbon emissions. For the Pedal boat, it contributes around 360 kg CO₂, while in the Sun boat, it exceeds 2300 kg CO₂, accounting for over half of the total emissions. This sharp increase indicates the quantity of epoxy resin used or a broader surface area being treated with the material. Aluminium also contributes notably, in the Sun boat approaching 950 kg CO₂. These materials are commonly used in structural components, and their high emission values highlight the environmental impact of metal selection in boat construction.

The Sun boat also features a wider variety of materials, including polystyrene foam slabs, iron-nickel-chromium alloys, sealing tape, silicone products, and plywood, which are absent in the Pedal boat. This suggests a more complex design, potentially with added insulation or

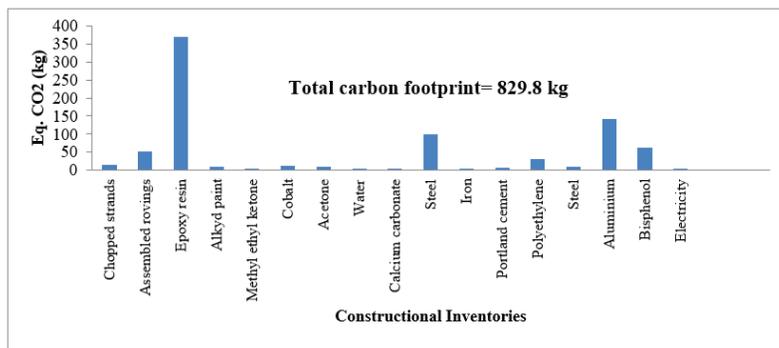


Figure 3. Constructional carbon footprint of Pedal boat

enhanced fittings, contributing further to its carbon footprint. Additionally, electricity usage, which is nearly negligible in the Pedal boat, plays a more substantial role in the Sun boat, possibly due to more energy-intensive construction methods, such as increased electrical or mechanical operations. Overall, these graphs (Figure 3 & 4) highlight the substantial impact of material choices and construction methods on the carbon footprint of fishing vessels. The consistent dominance of epoxy resin and aluminium in both cases suggests that targeted interventions in these areas could yield significant environmental benefits. Strategies such as the adoption of low-carbon alternative materials, optimization of material usage, and implementation of energy-efficient fabrication techniques are recommended to reduce the carbon footprint in future vessel construction.

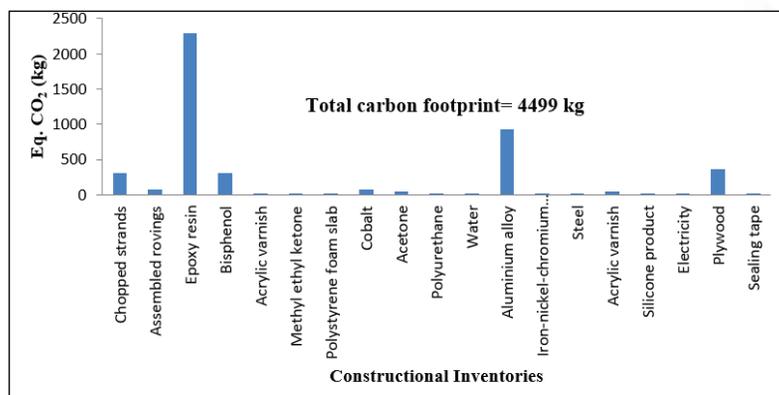


Figure 4. Constructional carbon footprint of Sun boat

Considering 25 years of service life of these boats, a replacement with single unit of Pedal and Sun boat can reduce 57,780 and 1,15,560 kg of CO₂ emissions, respectively, to the

environment (assuming the constructional footprint of Pedal/Sun boats will be nullified by the constructional footprint of commercial fishing boats). The effective and long-term solutions for the problem of fuel conservation due to fishing are restoration and enhancement of coastal fishery resources with the help of responsible fishing practices, including the use of an alternate renewable energy resource. If a single unit can make a visible contribution to reducing carbon footprint, then considering small-scale fishing systems of India as a whole would definitely make a significant change in greening the environment, helping achieve India's net-zero goal by 2070.

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Underwater observations on the socialization behaviours of Indo-pacific bottlenose dolphins from Andaman waters

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Andaman Nicobar Islands (ANI) are part of 572 islands, islets and rocks in Bay of Bengal. It covers a distance of almost 800 km over North-South, with a coastline of 1,962 km, and contributes to an Exclusive Economic Zone (EEZ) of 600 thousand km² to India. ANI comprises of two island groups - the Andaman Islands and the Nicobar Islands - which separate the Andaman Sea to the east from the Indian Ocean. The island's shelf topography supports fringing and barrier reefs, with passages and straights in depression, diverse rocky and sandy shorelines, and extensive mangrove swamps. ANI are one of the most diverse places in the world with a variety of marine environments that support an incredible biodiversity (Rajan et al., 2013). The islands are covered with a total of 105 protected areas, of which 15 are listed as Marine Protected Areas (Bijoor et al., 2018).

Andaman Nicobar Islands known for their abundant and diverse marine fishery resources, not only provide livelihood, food security and employment to the local population but also contribute to the national economy (Kiruba-Sankar et al., 2021; Ramakrishna & Sivaperuman, 2010). The island is also known for 16 species of marine mammals, including dugongs. Long-term observations show that 60% of the population declined during 1991-2012, mainly due to the interactions with fishing systems (D'Souza et al., 2013). Coastal fishing in ANI is primarily carried out by artisanal and small-scale fishers who use traditional fishing methods, such as gillnets, hook and line, and seine nets, to exploit resources in coastal ecosystems, such as mangroves and coral reefs (Ravikumar et al., 2015 & 2016). As per the report by the Department of Fisheries, A & N Administration (2023), the annual fish landings from the Island are estimated to be 31,058 tonnes, constituting 12.75% of the exploitable stock from these waters.

To study the interaction of marine mammals with the fishing systems and mitigation measures, ICAR-CIFT conducted a field study in the Andaman and Nicobar Islands. In this regard, aerial survey with Unmanned Aerial Vehicles and underwater observations were conducted in March, 2025. Two distinct pairs of bottlenose dolphins (*Tursiops* spp.) engaged in swimming and socialization behaviours, were observed and recorded underwater at a depth of 10 to 15 m in the Havelock Islands (12°00'83.7" N, 92°93'16.5" E) using GoPro Hero 12 camera (Figure 1).

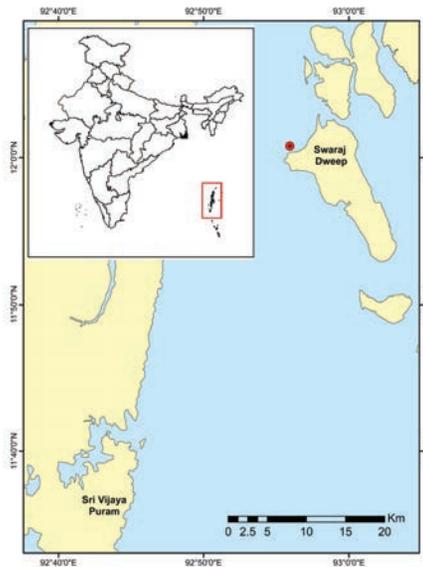


Figure 1. Study area

The bottlenose dolphin (*Tursiops* spp.) is one of the most distributed coastal dolphin species in the Asian region (Fanyi et al., 2025). In India, this species is listed under Schedule I of Wildlife (Protection) Act, 1972. It is one of the most researched species for its biology (Cockcroft et al., 1989; Cockcroft & Ross, 1990), population genetics (Natoli et al., 2008), population ecology (Kogi et al., 2004), and behaviour (Christiansen et al., 2010). In Australia and Japan, long-term monitoring projects conducted on *T. aduncus* reported a variety of distinctive behaviours and intricate social structures in the species (Connor et al., 2019). According to the geographical areas, due to human impacts, habitat features, and local oceanographic circumstances, the habitat and life history of this species differ significantly. The study conducted by Fury and Harrison (2008) revealed that a single location might not be effective in revealing the populations in other places.

In the present study, a short video clip lasting a minute on the actual interaction of the dolphins was recorded from multiple dive sessions. Key observations included swimming patterns, behaviour, and tactile contact between paired individuals. The water clarity, along with the GoPro's advanced low-light capabilities, enabled the recording of their interactions and fin movements precisely. Data on Sea Surface Temperature (SST), wind speed, and chlorophyll (a proxy for phytoplankton) etc. were collected from secondary sources during the day of observation. The SST in the sampling area was recorded as 29.89°C, while the Chl-a concentration was 0.215 mg/m³ (NASA OBP, 2020). Wind speed for the day was 3.95 m/s (GMAO, 2015). These factors may affect the occurrence, distribution and behaviour of the coastal dolphins as they impact the distribution of their prey, like small pelagic fishes, which are often found in areas with higher chlorophyll concentrations.

Bottlenose dolphins (*Tursiops* sp.) are highly social animals that live in a fission–fusion society in which some individuals associate more frequently than others within a stable wider social network (Connor & Wells, 2000; Wells, 2014). Video records revealed that the dolphins swam in pairs and exhibited synchronous swimming, where they coordinate their movements to enhance efficiency, communication, and social bonds. This synchronized swimming can involve maintaining specific positions relative to each other, such as side-by-side or one dolphin slightly behind and to the side of the other.

When dolphins swam horizontally parallel to the sea bottom, they often maintained precise spacing between individuals. Each dolphin kept an equal distance from the other, thus ensuring smooth, coordinated movement. Dolphins' vertical position in the water were also recorded, where their bodies are aligned straight up or down without any overlap of the body, dorsal fin, or pectoral fins (Figure 2). During group swimming, when two or more dolphins swam together in close proximity, they positioned themselves staggered above and below each other such that they could also see other individuals in the group (Norris & Dohl, 1980). It was less common for bottlenose dolphins to swim in parallel with each other than staggered vertically and horizontally in the water (Ashley, 2014). By keeping their fins and body separate, they maintained balance and stability while minimizing drag in the water.

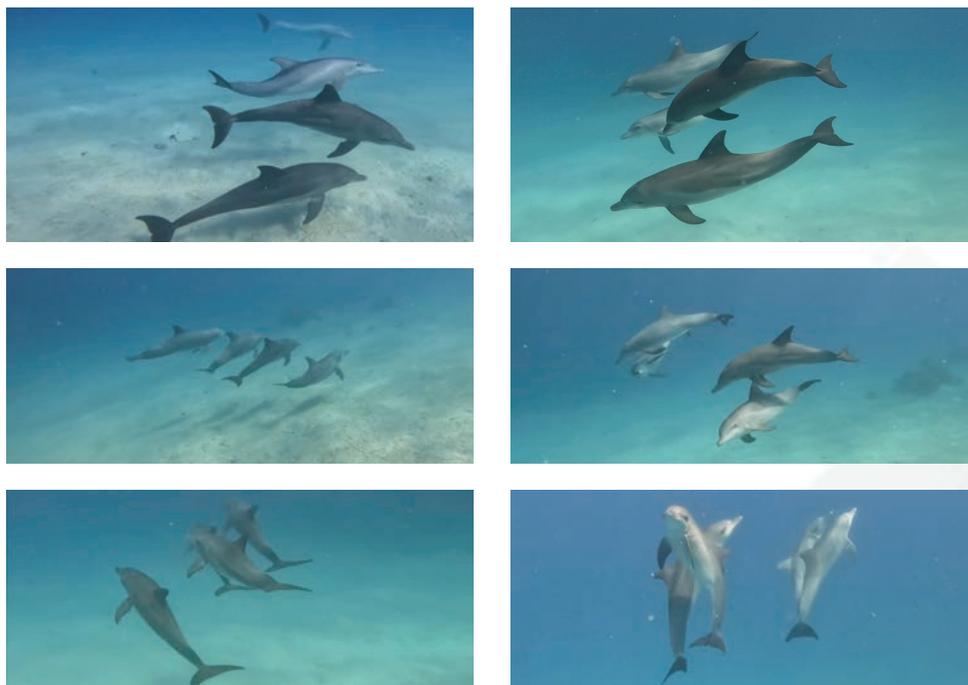


Figure 2. Underwater records on swimming pattern and socialization of bottlenose dolphin (*Tursiops truncatus*) from Andaman waters

Future research is aimed at expanding depth-specific behavioural observations to better understand habitat utilisation by Indo-Pacific bottlenose dolphins. Preliminary evidence indicated that the 10–18 m depth range may represent a key ecological zone, offering optimal access to prey, adequate light for visual communication, and reduced disturbance from surface activities. These insights underscore the need to incorporate three-dimensional habitat-based study in order to enhance conservation effectiveness compared to traditional two-dimensional frameworks.

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Transition from the Traditional Wood to FRP boat construction in Gujarat: A rising concern on environmental sustainability?

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Historically, Indian marine fishers predominantly utilized boats constructed from native timber, valued for their favourable physical, chemical, and mechanical properties, as well as their easy workability and long-lasting durability (Balasubramanyan, 1973). However, with the onset of mechanization and increasing integration of India's fisheries into global markets during the mid-20th century, there were significant changes in both the design and material composition of fishing vessels (Johnson, 2002). In India, around 239,000 fishing crafts are involved in marine capture fisheries, comprising approximately 59,000 mechanized, 76,000 motorized, and the rest non-mechanized units. Of the mechanized fleet, about 29,000 are trawlers (CMFRI-FSI-DoF, 2020). In Gujarat alone, a total of 26,103 marine fishing crafts have been recorded, with 64% made of wood, while the remaining vessels are constructed from fibreglass-reinforced plastic (FRP) (Gujarat Fisheries Statistics, 2024).

Due to increased cost and scarcity of boat-building woods, the search for alternative materials started in the late 1990s (Nasar & Baiju, 1991). Off-late, a substantial share of the motorized and non-motorized fleets, particularly those involved in small-scale fisheries (L_{OA} 8-12 m), have transitioned to FRP crafts, underscoring their central role in Indian fisheries. FRP is a composite material composed of polyester resin reinforced with woven glass fibres. With its rising applications across various sectors, including marine industries, the Asia-Pacific FRP market is expanding annually by about 7%, with India showing a growth rate of around 4.7% (Yi, 2017). In fisheries, FRP offers mechanically durable, flexible, and strong resistance to marine biofouling, making it particularly advantageous for coastal and small-scale vessels (Hopkinson et al., 2021; Shamsuddin, 2003). However, in recent times, the construction of mechanised boats (L_{OA} 14-17 m) using FRP materials is emerging in Gujarat, especially in the Saurashtra coast (Figure 1).

The transition from traditional mechanised wooden fishing boats to Fibreglass Reinforced Plastic (FRP) vessels marks a pivotal shift in Gujarat's marine fisheries (Figure 1). It has been estimated that every year, a total of 400-500 wooden mechanised boats are de-commissioned and the same number of new mechanised boats are constructed using FRP. This change is primarily due to political and economic reasons or due to the scarcity and supply shortage and rising cost of quality timber; thus, owners resorted towards alternative materials along with the growing need for vessels that are more fuel efficient and require less maintenance cost (FAO, 1980).



Figure 1. Material transition in marine fishing vessels along the Gujarat coast: Wooden hulls vs FRP moulds



Figure 2. A cluster of abandoned first-generation FRP fishing boats lying in the vicinity of the fish landing centre in Dhamlej village, Kodinar, Gujarat

Unlike wood, which is susceptible to borer attack and frequent repairs, FRP offers superior resistance to bio-fouling and smooth finish, leading to less resistance. Moreover, the incorporation of fibreglass reinforcements and a sturdy hull structure in boats enhances the high strength-to-weight ratio, which improves strength, reliability and fuel efficiency that benefits modern fishing operations (Harle, 2024). Additionally, its lightweight nature simplifies construction, transportation, and maintenance, thereby reducing costs and enhancing flexibility, which in turn enables the creation of innovative structures suited to diverse fishing needs (Gaurav, 2024). Despite these benefits, the widespread adoption of FRP boats presents several emerging challenges, especially concerning environmental sustainability and regulatory oversight. One pressing issue is the disposal of FRP vessels at the end of their operational life. Unlike wood and steel, FRP is non-biodegradable and difficult to recycle. As many of the first-generation FRP boats

reach the end of their service period, there is a growing trend of abandonment along coastlines, particularly in Gujarat (Figure 2). This reflects a global concern regarding plastic-based marine litter, similar to the issue posed by ALDFG and ghost gear exacerbates such as habitat degradation or microplastic pollution (Do & Armstrong, 2023). A study carried out along the Chellanam coast of Kerala revealed that FRP materials from High Water Level (HWL) and boat disposal sites showed 5% and 36%, respectively, of the total plastic debris collected (Lekshmi et al., 2023). Furthermore, the deterioration of FRP boats leads to the release of microplastics into the marine ecosystem due to their polyester-based composition (Lekshmi et al., 2023). The recycling of FRP boats poses considerable challenges, especially thermoset FRP, which cannot be reheated, melted and reused due to the presence of a permanent cross-linked resin matrix (Yi, 2017). Although effective recycling systems exist for many traditional materials, scalable and commercially viable solutions for polymer composites such as those used in FRP boats remain limited (Galgani et al., 2025). This gap highlights the urgent need for innovation in composite recycling technologies to meet growing environmental demands and circular economy goals.

Recommendations

Recycling abandoned FRP boats is challenging, but mechanical recycling, where boats are crushed into small pieces, ground into a powder, and used as filler in new products like concrete or other FRP items, is possible. Additionally, alternatives such as pyrolysis or solvolysis should be explored for improved FRP recycling. A proper disposal facility for the FRP boats may be created for all major fish landing centres and fishing harbours. Awareness campaigns at the community level, such as beach cleanup programmes and fisher engagement initiatives, should align with national missions like *Swachhta Action Plan* (SAP) to foster a culture of sustainable disposal practices. An increased tax on the FRP materials may reduce the new FRP fishing vessel construction. In summary, the shift from wood to FRP in fishing boat construction reflects the dynamic evolution of India's marine fishing crafts. While FRP boats offer undeniable advantages in terms of performance and fuel efficiency, their environmental impact at the end of their lifecycle necessitates immediate attention. A balanced approach combining technological innovation, regulatory frameworks, and community engagement will ensure that this paradigm shift supports not just fisheries growth but also marine ecosystem sustainability.

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Development of Air-Fried Squid Jerky: Two-Stage Process Optimization

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Squid is a highly nutritious and versatile seafood that offers significant health benefits. It is a lean source of high-quality protein, low in fat and calories, making it ideal for weight management and heart health. Rich in essential nutrients like vitamin B12, selenium, phosphorus, and omega-3 fatty acids, squid supports nerve function, energy metabolism, and cardiovascular health. Including squid in the diet boosts nutritional intake while adding a flavourful and wholesome element to meals. Squid's versatility extends beyond its fresh form, being processed into various products to meet diverse consumer demands. These products fall into three categories: semi-processed, ready-to-eat (such as squid silk, shredded squid fillets, and smoked squid rings), and canned. This wide product range caters to different tastes, fuelling growth in the squid processing industry. The rising popularity of squid products underscores its potential as a nutritious and economically valuable ingredient in the global food market.

Jerky is a popular ready-to-eat dried meat product known for its convenience, long shelf life, rich nutrients, high protein content, and low fat (He et al., 2023). Traditionally produced from beef, health concerns related to cholesterol have driven interest in alternative sources such as squid. Squid-based jerky offers nutrient rich, low-cholesterol value-added product that enhances under-utilized marine resources. As consumer demand increases for healthier, organic, and allergen-free foods, squid jerky represents a promising innovation in the functional snack market. Drying techniques including sun drying, air drying, smoking, and microwave drying techniques are essential in seafood processing, as they reduce water activity, extend shelf life, and enhance safety and flavour. Air frying is a modern, little to no oil cooking/drying method that uses hot air to mimic the appearance and texture of traditional frying. It offers rapid drying, efficient heat transfer, better nutrient retention, and shorter processing times, making it an increasingly popular and healthy option for preparing aquatic muscle foods (Wang et al., 2024). In squid jerky production, air frying can serve as an effective drying technique when temperature and time are optimized, resulting in a flavourful, nutritious, and shelf-stable product. This study aims to optimize air frying parameters for the development of high-quality squid jerky, aligning with the growing demand for healthy and high-protein snack options.

Fresh squid was procured from a reliable seafood supplier in Kochi, Kerala, and other ingredients such as soy sauce, Worcestershire sauce, garlic powder, onion powder, black pepper,

chilli flakes, and salt were sourced from well-stocked local supermarkets. Upon procurement, the squid was cleaned, tentacles removed, thoroughly washed, and sliced into uniform strips measuring approximately 4.5 cm in length and 1.5 cm in width. The prepared squid slices were immediately packed, blast frozen, and stored in a deep freezer at $-18 \pm 2^\circ\text{C}$ to preserve quality.

For jerky preparation, the frozen squid was thawed overnight at 2°C . About 100 g of the thawed squid was subjected to a pre-drying step in an air fryer at 100°C for 30 minutes. Following this, the squid was marinated with a blend of ingredients and refrigerated for 2 hours to allow proper absorption of flavours. After marination, the squid stripes were air-dried again, with drying optimized at 100°C for another 30 minutes (Figure 1). The final squid jerky was then evaluated for nutritional composition, sensory characteristics, biochemical and microbiological quality parameters.

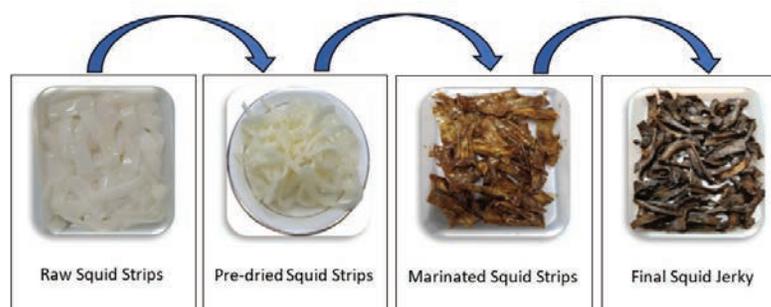


Figure 1. Steps in air-fried squid jerky development

The study evaluated the proximate composition of squid jerky by standard AOAC (2019) methods; biochemical and microbiological quality parameters, such as Total Volatile Base Nitrogen (TVBN), Thio barbituric Acid (TBA), and Total Plate Count (TPC), were determined to assess the quality of the product (AOAC, 2019; AOCS, 2005; Maturin & Peeler, 1998). The sensory characteristics of the product were assessed based on five key attributes: colour, aroma, taste, texture, and overall acceptability (OA). These attributes were evaluated using a nine-point hedonic scale outlined by Meilgaard et al. (2007), where higher scores indicated greater liking.

Proximate composition analysis was carried out on both raw squid (RS) and the final squid jerky (SJ). The raw squid sample was found to contain 77.47% moisture, 3.39% ash, 2.30% crude fat, and 16.12% crude protein. In comparison, the squid jerky exhibited a significantly reduced moisture content of 19.96%, indicating substantial dehydration during the drying process. The concentrations of crude fat, ash, and crude protein in the squid jerky increased relative to the raw sample as given in Table 1. This is attributed to the reduction in moisture content during air drying, which concentrates the remaining nutritional components. The drying process, driven by heat and airflow, removes water from the food matrix and results in dehydration, which decreases moisture content and leads to a corresponding increase in the relative proportions of other nutrients such as protein and fat.

Table 1. Proximate comparison of raw squid and squid jerky

| Sample | Moisture (%) | Ash (%) | Fat (%) | Protein (%) |
|-------------|--------------|---------|---------|-------------|
| Raw Squid | 77.47 | 3.39 | 2.30 | 16.12 |
| Squid Jerky | 19.96 | 7.34 | 4.85 | 56.78 |

The observed TVB-N value of squid jerky was 22.68 mg/100g, which falls within the acceptable limit of TVB-N. The processed squid jerky had a TMA value of 4.1 mg/100g, which is also within the acceptable range, confirming their quality and freshness. The TBA value of squid jerky was found to be 1.03 mg/Kg. Total Plate Count (TPC) analysis revealed a decrease in microbial load after drying, indicating improved freshness and shelf stability of the squid jerky. The reduction in TPC values resulted from lowered moisture content and thermal effects during processing, which created unfavourable conditions for microbial growth. The TPC value of raw squid was 1.3×10^5 cfu/g, which reduced to 1.6×10^3 cfu/g in the final product as given in Table 2. These findings demonstrated that the drying process effectively enhances the product's microbial quality, which can help to extend its shelf life. The histamine content of the squid jerky was 3.66 mg/Kg, a value within the acceptable limits.

Table 2. Microbiological values in the process line of squid jerky

| Sample | TPC (cfu/g) |
|-----------------|-------------------|
| Raw squid | 1.3×10^5 |
| Pre-dried squid | 1.2×10^3 |
| Marinated squid | 4.0×10^4 |
| Squid jerky | 1.6×10^3 |

A panel of 10 semi-trained individuals conducted the sensory evaluation, and the results illustrated high acceptance of the product with favourable ratings across all measured parameters (Figure 2). The positive feedback from the panel suggests potential consumer acceptability and overall satisfaction with the product's sensory qualities.

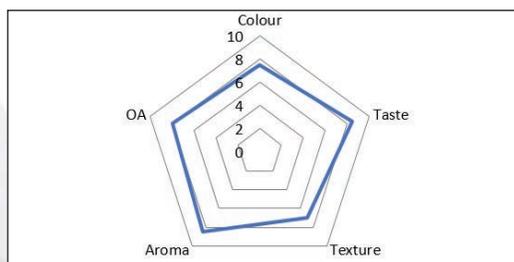


Figure 2. Sensory evaluation of squid jerky

This work aimed to develop high-quality squid jerky by optimizing air-frying conditions, specifically time and temperature. The best results were achieved using a two-step air-frying process: pre-drying squid strips at 100°C for 30 minutes, followed by marination and seasoning, then post-drying at 100°C for 20 minutes. This method yielded jerky with desirable moisture content (<20%) and sensory qualities. Nutritional analysis, biochemical evaluation and microbiological analysis showed the product was within safe and acceptable limits. A previous study by Joshy et al. (2020) identified 180°C for 12 minutes as the optimal air-frying condition for fish cutlets, resulting in desirable sensory and nutritional characteristics such as improved colour, texture, and protein content. Overall, the results indicate that air-fried squid jerky under optimized conditions not only preserves its nutritional integrity but also significantly enhances its overall quality, making it a promising, shelf-stable, and nutritious snack option.

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Microalgae gel beads: A convenient and palatable nutrient delivery system

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Microalgae are considered to be an important source of biomolecules, including protein, lipid, carotenoids, phenolic compounds, and carbohydrates that can be harnessed for both feed and food applications. Because of their ecological adaptation and low land requirements, microalgae have been promoted as a potential source of alternative protein and nutrients. The food applications of microalgae have been explored to a greater extent in the past decade and are continuing as an important research area across the world. Microalgae have protein content varying from 1-14% on a wet-weight basis or 6-71% on a dry-weight basis, and a few of them have higher protein content than terrestrial crops (Wang et al., 2021). In India, the utilization of microalgae as a food product is mostly focused on *Arthrospira* (spirulina) and *Chlorella* sp. Unfamiliarity with microalgae food products and the strong earthy/seaweed flavour of microalgae are the major limiting factors for the acceptability of microalgae as food products. This can be overcome by 'product innovation' *i.e.*, changing the texture of the algae for increasing consumer's acceptance. Encapsulating microalgae in gel beads is a promising approach to enhance consumer acceptability. Besides, it can be used as a tool to protect the nutrients, mask their natural flavour, and make them more palatable to consumers. The marine microalgae belonging to the genus *Nannochloropsis* contain a rich amount of protein, PUFAs, carbohydrates, and are being used in nutraceutical and functional food development (Zanella & Vianello, 2020). This species is reported to have 20-30% protein (Matos et al., 2017) depending on the culture conditions, indicating its potential to boost the protein content when incorporated into suitable food products. The present article describes a process for developing microalgae gel beads using sodium alginate as a carrier.

The *Nannochloropsis gaditana* was purchased from M/s Jemmax Nutraceuticals Private Limited, Tirunelveli, Tamil Nadu. The proximate composition parameters, such as protein, moisture, fat, and ash were estimated by standard AOAC procedures (AOAC 2016). For preparing the algal beads, *N. gaditana* paste was added to the sodium alginate solution and thoroughly mixed using a magnetic stirrer. The solution was then allowed to stand for 2 h at refrigerated

temperature (4°C) to release the trapped air bubbles. The gel beads were prepared by dropping the alginate solution containing *N. gaditana* into a calcium lactate solution. Different concentrations of alginate solution were tested to evaluate the bead's size, shape, the number of beads per minute, weight of beads and yield.

The *N. gaditana* paste had 61.24% moisture, 12.31% protein, 1.92% lipid and 8.12% ash. The protein level of *N. gaditana* indicates its potential as a protein source in food products. Similarly, the mean value of ash content obtained in *N. gaditana* shows that this microalgae species is a rich source of minerals. Zanella and Vianello (2020) reviewed the nutritional composition of *Nannochloropsis* genus reported by various researchers, and the protein content of *N. gaditana* was reported as high as 47% on dry-weight basis. Similarly, Maoneze and Martinez (2023), reported that minerals are a significant component of microalgal biomass and the level can vary from 2-40% of its dry mass. However, the lipid content obtained for *N. gaditana* was far below than those reported by Zanella and Vianello (2020).

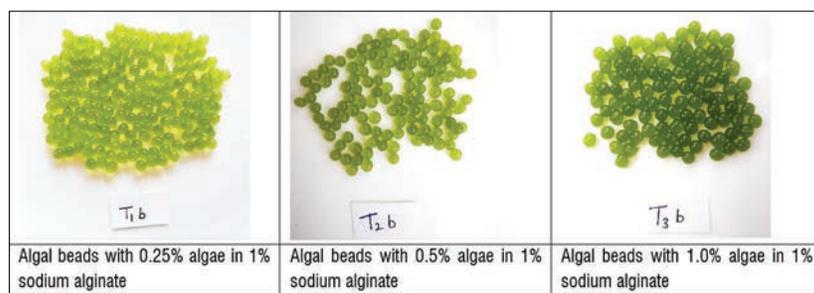


Figure 1. Microalgal beads prepared from *N. gaditana*

When alginate solution was dropped into calcium lactate solution, the calcium ions crosslinked with the functional groups of alginate (guluronic acid and mannuronic acid), forming a gel on the surface of contact, entrapping the ingredient. The physical properties of the beads were compared in order to decide the optimum concentration of sodium alginate to make the perfect round-shaped beads. Sodium alginate is a biocompatible and non-toxic carrier material being used as a carrier for the delivery of nutrients/bioactive compounds. The experiment demonstrated that the concentration of sodium alginate had a major influence than microalgae on the physical properties of the beads. Alginate when used at 1% yielded perfect round-shaped beads. Therefore, 1% alginate can be considered the optimum concentration for achieving perfectly round-shaped beads with a good yield.

The concentration of microalgae influenced the weight and color values of the beads. This is expected because when the microalgae concentration increases, it contributes to an increase in the mass per unit volume of beads (Figure 1). The lightness (L^*) value of beads had reduced with

the increase of microalgae level, and the greenness value was elevated in beads prepared with 1% algae because of the abundance of chlorophyll content. At each algal concentration tested, the lightness value increased with an increase in alginate concentration.

Microalgal beads can find applications in the food industry for convenient delivery of microalgal nutrients and bioactive compounds. The expected areas of applications are beverages, health drinks, salads, food toppings *etc.* Further investigation on the development of flavored beads with a higher concentration of microalgae will be carried out to diversify its food applications.

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Tapping Myctophids as an unexploited source of nutraceuticals: A preliminary study

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Myctophids, also known as lanternfishes, belonging to the Myctophidae family, are mesopelagic fishes distributed abundantly in the regions spanning from 200-1000 meters below the surface of the ocean, globally across the oceans, especially the Southern Ocean. They are very small fishes, with a total biomass of approximately one billion tons, yet are underutilized and least studied, being generally considered as bycatch and discarded back to the Ocean. Only a small portion of these fishes are utilized in the form of fishmeal, fish oil *etc.* (Hidalgo & Browman, 2019; Huang et al., 2021; Saunders et al., 2019; Shaviklo & Rafipour, 2013), evidencing that their nutraceutical potential remains unexplored.

Myctophid fishes are rich in long-chain omega-3 polyunsaturated fatty acids (PUFAs), particularly eicosapentaenoic acid (EPA, C20:5), and docosahexaenoic acid (DHA, C22:6), which are known for their anti-inflammatory, cardiovascular, and neuroprotective properties (Calder, 2015). Similarly, they are also rich in fat-soluble vitamins such as vitamin A, D₂, proteins, lipids, wax esters, *etc.*, which are important biomolecules having the role in bone health, antioxidant activity, and immunity *etc.* (Huang et al., 2021; Nevenzel et al., 1969; Theofylaktos et al., 2023; Zhang et al., 2023). This research suggests that they can be very well explored as a source of nutraceuticals by using effective and appropriate extraction techniques. Advanced lipid extraction and separation techniques, like supercritical fluid extraction (SFE), can be applied to extract lipids and oils from these sources. The residual biomass, after the extraction, contains high protein content, which is suitable for aquafeed production, thereby enabling the utilization of the full biomass.

Supercritical fluid extraction (SFE) uses supercritical fluids, particularly supercritical carbon dioxide (scCO₂), which shows both gas-like properties and liquid-like density, such as diffusivity, viscosity, and compressibility, ensuring effective extraction of bioactive components (Melgosa et al., 2021). This allows selective extraction of oils that contain lipids, wax esters, *etc.*, without the use of harmful solvents or extreme heat, thereby retaining the thermosensitive compounds like vitamins and PUFAs.

The biomass of myctophids, obtained as residue after the lipid extraction process, has enormous potential in aquaculture owing to their nutritional richness. The defatted biomass is known to be rich in proteins, essential amino acids, and minerals. The remaining protein-rich mass after extraction can hence be processed into high-value aquafeed ingredients. Formic acid-induced ensilaging of the myctophid fish, namely, *Neoscopelus microchir* and *Diaphus watasei*, when combined with rice bran (2:1), has been shown to increase protein availability, with a crude protein content of 35.30%, showing its potential as an aquafeed ingredient (Anas et al., 2024).

The present study mainly focused on evaluating the proximate composition and fatty acid profiling of two myctophid fish species, namely, *N. microchir* and *D. watasei*, to explore their nutraceutical potential. The results revealed a crude protein content (on dry-weight basis) of 69.58%, crude fat content of 20.08%, and ash content of 8.24% in *N. microchir*. Similarly, *D. watasei* showed crude protein, crude fat, and ash content of 57.35%, 25.33%, and 7.79%, respectively. These results indicate that both species are rich in macronutrients, particularly lipids and protein, supporting their potential use in nutraceutical development. A comparatively lower protein content (on wet-weight basis) values of 14.45- 16.54% in *D. effulgens* and *D. hudson* has been reported by Fernandez et al. (2014).

The fatty acid profiling of the selected fishes, showed a diverse composition of saturated, monounsaturated, and polyunsaturated fatty acids, highlighting their nutritional potential. In case of *N. microchir*, oleic acid (C18:1) was most abundant (25.70%), followed by palmitic acid (C16:0), 22.12%, and docosahexaenoic acid (C22:6, 13.91%) while in the case of *D. watasei*, oleic acid was the dominant (33.33%), followed by palmitic acid (17.48%) and DHA (8.60%). Eicosapentaenoic acid (EPA, C20:5) was also present in notable amounts: 3.36% in *D. watasei*, and 5.23% in *N. microchir*. Similar findings stating DHA as the most dominant fatty acid, followed by EPA in myctophids, have been reported by Navaneethan et al. (2014).

The presence of other fatty acids like palmitoleic (C16:1), arachidonic (C20:4), and linoleic acid (C18:2) contributes to the overall functional and nutritional value of the fish. Figure 1 and Figure 2 represent the Total Ion Chromatogram (TIC) of the fatty acid methyl esters (FAME) extracted from *D. watasei* and *N. microchir*, respectively.

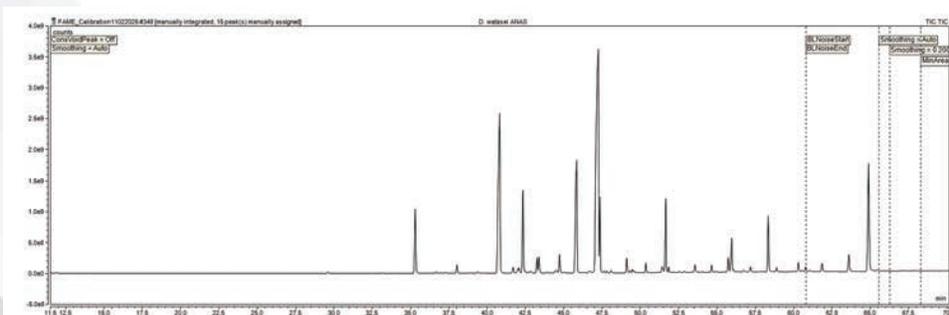


Figure 1: Total Ion Chromatogram (TIC) of fatty acid methyl esters (FAMES) extracted from *D. watasei*

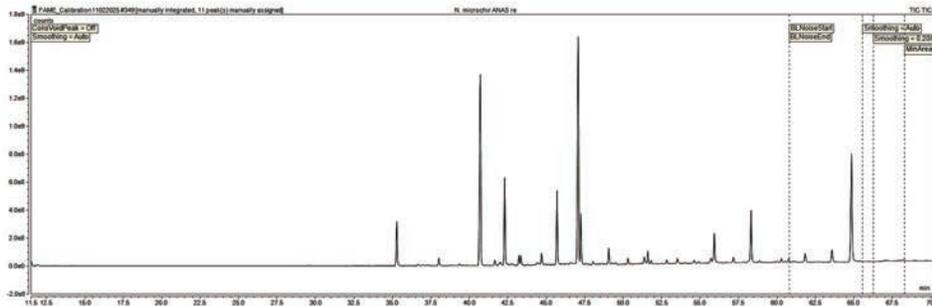


Figure 2: Total Ion Chromatogram (TIC) of fatty acid methyl esters (FAMES) extracted from *N. microchir*

To conclude, myctophids represent a promising yet underutilized marine resource with great potential in the field of nutraceuticals. The findings of this study highlight the nutritional potential of two underutilized myctophid species, namely *N. microchir* and *D. watasei*, for nutraceutical applications. The high levels of protein and fat content in both species suggest their application in nutraceuticals and aquafeed development. The fatty acid profiling confirmed the presence of significant amount of long-chain omega-3 fatty acids, including EPA and DHA, as well as oleic and palmitic acids, among other fatty acids. The application of green extraction techniques, such as Supercritical Fluid Extraction (SFE), ensures the isolation of these bioactive compounds by retaining their quality. With the increasing demand for natural, marine-based sources like omega-3 PUFAs and other bioactive compounds, the inclusion of myctophid oils and their extracts into nutraceutical products presents a promising approach to support environmental sustainability and human health. These results promote the sustainable use of myctophid as a valuable marine source for functional food and nutraceutical development.

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Quality attributes of clam (*Villorita cyprinoides*) dried using infrared dryer

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The food industry uses infrared radiation (IR) as a source of energy for different unit operations like drying, pasteurization, roasting, blanching, *etc.* IR drying can be hybridized with other drying techniques, including hot air, microwave, freeze-drying, and vacuum, for accelerating the speed of the process and to achieve improved outcomes (Sakare et al., 2020). Integration of IR heating with present drying techniques, helps to produce dried food materials of superior-quality. IR drying has a wide range of key benefits, such as rapid heat transfer, uniform heating, faster processing, high efficiency (80–90%), energy savings, cost-effectiveness, and enhanced product quality. Recent studies have reported the employment of IR dryers for processing of marine products (Delfiya et al., 2022).

Clam meat is a rich source of protein and acts as highly nutritious food among seafood (Narasimham et al., 1996). Clams are considered a healthy food because they are rich in nutritious elements such as vitamins, minerals, essential amino acids, peptides, and long-chain polyunsaturated fatty acids. The drying of clams is mainly done to reduce the water activity of fresh aquatic products, thereby reducing microbial growth. The preservation of dried clams is easier, and they have good quality in terms of flavor and nutritional profile. Dried clams are also convenient to transport and hence are of more demand among the customers (Xie et al., 2018).

The clams are consumed as curry or fried meat, and small quantities are exported in dried and frozen conditions. In the consumer market, the products developed from clams, such as dried, pickled, and canned products, are not commonly available. Under this scenario, on ensuring its availability in the market, these products can be popularized due to its demand. Hence, this study was carried out to standardize dried clam with superior quality attributes. Clam drying was carried out using IR dryer developed at ICAR-Central Institute of Fisheries Technology, Kochi, Kerala (Delfiya et al., 2024).

Fresh black clam (*Villorita cyprinoides*) purchased from local fish market in Kochi was washed thoroughly using potable water and blanched in hot water (90°C for 3 min) to reduce

the initial microbial load in sample. A pilot-scale IR dryer with hot air assistance (Figure 1) was used in this study with the following operating conditions: 3000 W/m², 10 cm exposure distance, drying air temperature of 45°C, and air velocity of 1.5 m/s. The initial moisture content of the clam was estimated by the hot air oven method (AOAC, 2019). Weight loss during drying was measured at 30 minute intervals. The drying parameters, such as moisture reduction, drying rate, shrinkage, and rehydration ratio, were estimated during and after the drying process. The quality parameters, viz., colour, pH, thiobarbituric acid reactive substances (TBARS), total volatile basic nitrogen (TVBN) and total plate count (TPC) were analyzed in the dried clam samples.



Figure 1. Pilot-scale IR dryer with hot air assistance used for clam drying

A total drying time of four hours was recorded to reduce the moisture content of the clam from 79.35% to 12.43% on wet basis. The highest drying rate of 3.34 (kg water/kg dry matter. h) was observed at 0.5 h and gradually reduced as drying progressed. The quality characteristic of clam samples is indicated in Table 1.

Table 1. Quality characteristics of clam dried using infrared dryer

| Parameters | Fresh clam | Dried clam |
|-----------------------------|----------------------|---------------------|
| Shrinkage (%) | - | 21.71±0.2 |
| Rehydration ratio | - | 2.02±0.05 |
| Colour value | | |
| L* | 58.77±0.15 | 33.17±0.11 |
| a* | 1.69±0.06 | 5.68±0.08 |
| b* | 12.44±0.07 | 18.70±0.04 |
| Total colour change (ΔE) | - | 26.67±0.03 |
| pH | 6.48±0.02 | 7.08±0.01 |
| TBARS (mg malonaldehyde/kg) | 2.55±0.1 | 3.85±0.3 |
| TVBN (mg/100g) | 7.62±0.05 | 11.02±0.07 |
| TPC (CFU/g) | 2.85×10 ⁵ | 5.5×10 ² |

Shrinkage and rehydration values indicated the lower physical changes and higher moisture absorption, approximately 2-fold characteristics of the clam dried using the infrared dryer. Clam became darker upon drying, and the redness as well as yellowness values were increased in the dried clams. The variations in colour of the clam must be on account of the Maillard reactions and pigment concentration. TBARS measures the lipid oxidation, and the increase in this parameter in dried clam might be the result of the oxidation that occurred during drying. However, the values were within acceptable limits for dried seafood. TVBN is a freshness indicator, and hence a moderate increase was expected due to drying-induced concentration. Values under 25-35 mg/100g are generally considered acceptable for dried or salted seafood (EC, 2005). Moreover, the specific TVBN values change based on the type of fish, drying method, and storage conditions. Microbial reduction during drying indicated the effectiveness of infrared drying in microbial safety enhancement. Overall, from the study, it was inferred that the IR process maintained acceptable rehydration, pH, and quality characteristics suitable for storage and consumption.

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Protocol optimization for the isolation of seaweed associated endophytic bacteria

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Endophytic microorganisms inhabit in the intercellular tissue of plants without causing harm to their host. All plants, including aquatic micro and macroalgae, were found to possess these microorganisms. Several endophytes secrete bioactive substances such as secondary metabolites, which prevent other microbes from growing in their natural habitat. Endophytes have a synergetic effect on their host, promoting healthy condition in terms of normal morphology and physiology. They secrete substances that either aid the host in defence strategies or cause morphogenesis. Research on endophytes has been more extensive in terrestrial plants compared to aquatic plants. However, aquatic plants, and seaweed in particular, have received less attention in endophytic research despite evidence that endophytes reside in these environments.

The microbiota of seaweed includes both epiphytes and endophytes, and its composition is influenced by several biotic and abiotic factors. Epiphytes, which live on the seaweed surface, are widely distributed in the environment. Microflora originating from soil and water become part of the epiphytes. Depending on the nature of these extraneous contaminations, the microorganisms can be useful or harmful. Unlike epiphytes, the endophytes have the ability to influence the distribution of other microbes on their host. The novel bioactive secondary metabolites identified in seaweed endophytes include phenolic acids, alkaloids, quinones, steroids, saponins, tannins, and terpenoids (Muhilan et al., 2023). These metabolites are known for their antibacterial, antioxidant, anticancer and numerous other bioactive properties. Many seaweed endophytes have the potential to function as biocontrol agents against clinically relevant pathogens, zoonotic pathogens, and aquatic pathogens. Addition of active endophytes in fish feed promoted disease resistance in the aquaculture species (Deutsch et al., 2021). One of the promising bacterial endophytes of seaweed origin is the genus *Bacillus*, which has emerged as a viable probiotic candidate and a significant biocontrol agent, especially in the aquaculture sector. Plants, including those of aquatic origin, have a diverse community of endophytic microorganisms such as bacteria, fungi, actinomycetes and viruses. Interestingly, many of these are biotrophic in nature, and the isolation and cultivation of these microorganisms in laboratory conditions are quite challenging due to the lack of essential nutrients or growth factors in commonly used microbiological media. Another challenge is recovering endophytic microorganisms from contaminating epiflora from the

surrounding environment. Hence, protocol optimization is essential for the isolation of endophytic bacteria, considering the unique characteristics of the seaweed and its habitat. Established protocols are available, which explain the isolation of endophytes from seaweed (Deutsch et al., 2021; Sugrani et al., 2019). In the present study, an attempt was made to recover the endophytic bacteria from *Ulva intestinalis*, a green seaweed (Figure 1).

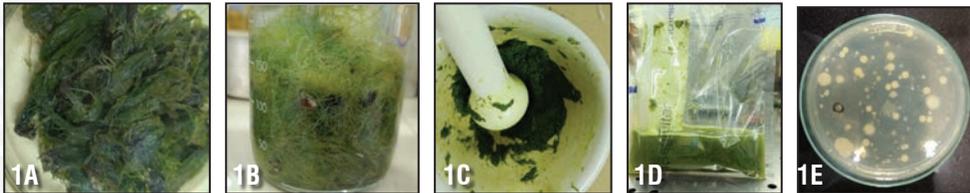
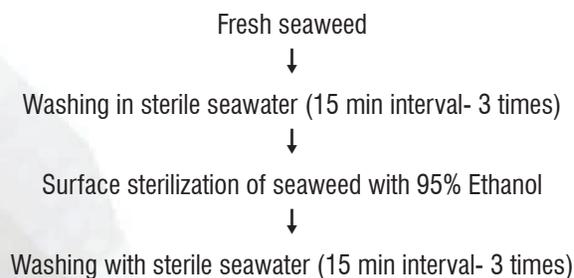


Figure 1. Green seaweed (*Ulva intestinalis*) 1A) Before washing; 1B) After washing; 1C) After grinding; 1D) Homogenized seaweed in sterile seawater; E) Bacterial colonies on marine agar plate

The protocol for the isolation of endophytic bacteria from seaweed was optimised by following several washings of the seaweed sample with sterile seawater (Figure 2). Surface sterilization of seaweed was carried out using disinfection agent (95% ethanol) followed by washing in sterile seawater (salinity 35 ppt), which improved the recovery of the endophytes. Many endophytes may be slow growers or show poor growth performance in laboratory media. A longer incubation of 3-5 days at 25°C on marine agar plates yielded the isolation of slow-growing bacteria. Homogenization or proper grinding of the seaweed sample and use of agar media prepared in sterile seawater improved the recovery of the endophytes. Using sterile seawater as diluent for plating also improved the recovery of the endophytic bacteria. The washed seaweed sample showed a significant reduction in bacterial count (Log_{10} 3.035 CFUg⁻¹ wet weight) compared to the unwashed seaweed sample (Log_{10} 5.57 CFUg⁻¹ wet weight) after seven subsequent washes in sterile seawater (3 times), 95% ethanol (1 time) and final washes in sterile seawater (3 times), respectively (Table 1). Some specific strategies or considerations can be helpful while isolating endophytic bacteria from seaweeds, such as using appropriate media and growth conditions that mimic their natural environment, using specific techniques or reagents or enzymes that lyse the algal cells, and adding specific ingredients or signal compounds.



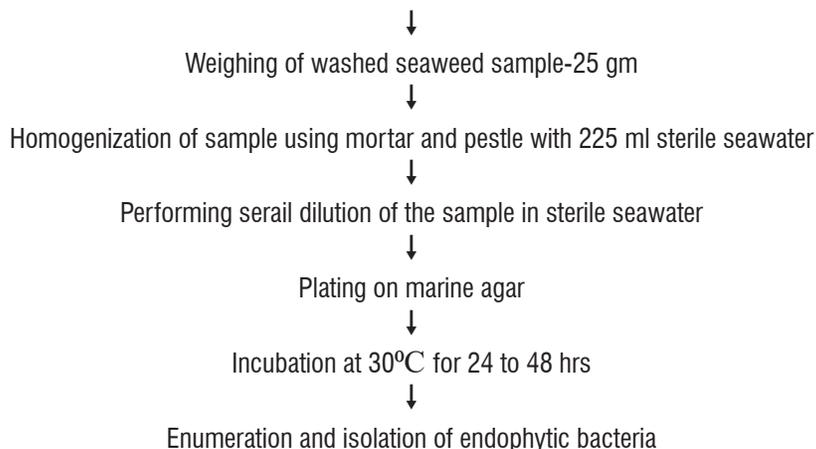


Figure 2: Flowchart depicting isolation protocol of endophytic bacteria from fresh seaweed (*U. intestinalis*)

Table 1. Effect of washing on reduction of microbial count from fresh seaweed sample (*U. intestinalis*)

| Seaweed sample | Washing time | Bacterial count (Log CFU gm ⁻¹ wet weight) |
|-------------------------------|--------------|---|
| Unwashed (control) | 0 min | 5.57 |
| Washing with sterile seawater | 15 min -3X | 4.52 |
| Washing with 95% Ethanol | 15 min-1X | 3.04 |
| Washing with sterile seawater | 15 min-3X | 3.03 |

'X' represents the number of washes.

Matrix specific isolation strategies are important for recovering bacteria of ecological as well as biotechnological importance. The multifaceted isolation approaches are need to be compared and validated further to understand the bacterial diversity. The research has been initiated to explore the bacterial diversity associated with seaweed for its potential application in biotechnological field.

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Pattern and impact of communication on domestic price formation in Kerala's marine fisheries sector

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Introduction

Generally speaking, the price of fish is determined at the landing centre by the interplay of demand and supply. In marine fisheries, traditional price determination has historically relied mostly on face-to-face bargaining at landing centres, based on prevailing market demand and supply conditions. This conventional system often fosters information asymmetries between producers, intermediaries, and consumers (Shyam et al., 2023). The advent of communication technologies, particularly mobile phones and wireless networks for sharing market price information, has emerged as a transformative force in mitigating these issues. These advancements have made fish markets more efficient and have enhanced both producer and consumer welfare (Srinivasan & Burrell, 2013). An efficient marketing system can be described as one characterized by complete market integration and quick price transmission, where prices adjust instantly in response to any internal or external changes affecting the market (Shyam et al., 2023; Squires, 1990).

In recent years, domestic price formation in the marine fisheries sector has been influenced by multiple factors, with communication and information flow emerging as a key determinant. Effective communication among fishers, wholesalers, retailers, and consumers shapes how market information such as demand, landings, and quality is exchanged and utilized. In Kerala, where traditional fish marketing systems coexist with digital and cooperative networks, unequal access to timely information often results in asymmetric price transmission and income disparities across market actors. Understanding the impact of communication mechanisms on price formation is therefore vital for enhancing marketing efficiency and ensuring equitable returns to producers and consumers. This study examines how formal and informal communication pathways influence price dynamics in Kerala's marine fish markets, focusing on information asymmetry, market linkages, and intermediary roles.

A mixed methods approach was adopted, combining primary and secondary (archival research) approaches. Data on communication methods, price information, fish marketing, marketing channels, and price determination were collected through face-to-face interviews with 54 fishers, covering the heterogeneous nature of craft-gear combinations in Kerala across four landing centres as well as harbours representing different geographical regions - Vellayil (10 units) and Puthiyappa (12 units) from Kozhikode district, Kollam Port (20 units) from Kollam district, and Chettuva–Munakkakadavu (12 units) from Thrissur district. The study used a structured interview schedule and physical observation. This study uses data from cross-sectional surveys conducted at these centres, collected as part of a Kerala State Planning Board-funded project titled “Marine Fishery in Kerala: A Study on the Evolution of Policy, Cost and Earnings of Fishing Units, and Income of Fisher Households.” The cost and earnings surveys were carried out between 1st April 2023 and 31st March 2024. Secondary sources consist of published articles and materials to support primary evidence and the changes happening in the system over a period of time in fish marketing and price determination.

In India, fish is marketed through different channels and outlets. The process begins with individual farmers who produce fish from various sources, process them, and make them available for market. It ends with the consumers, who is the final one, to either eat or convert the fish into a different form (Bisoyi, 2005; Jadhav & Borgave, 2020). Among these distribution channels, there are various types of functionaries-auctioneers, commission agents, traders, and wholesalers at the landing center, interior wholesalers, and retailers at last (Sathiadhas & Narayanakumar,1994).

Marine fish marketing in India is marked by high variability in both demand and supply, the presence of multiple marketing channels and intermediaries, and frequent price fluctuations (Aswathy & Abdussamad, 2013; Johnson et al., 2021). The interaction between demand and supply at landing centres and retail markets ultimately determines the price (Johnson et al., 2021; Salim et al., 2023; Sathiadhas & Narayanakumar, 1994).

In Kerala, at the landing centers, the method of price determination is by open auctioning and weight basis through an authorized auctioneer in the harbour. This provides maximum competition among buyers and helps in quick disposal of fish. Generally, the auction is conducted by a traditional or authorized auctioneer on a commission basis, who takes responsibility for realizing the sale proceeds from the buyers. They act as a liaison between the seller and the

buyer and charge for their service in the form of a commission. The auctioneer usually takes 2-10% of the fish they auction as a commission (Suresh, 2023). The commission rate varies across landing centres and harbours. Since many auctioneers provide advance loans to fishers, they take part of the share towards the interest on the loan advanced. Direct participation in the market and sales operation by retailers, wholesalers, and export companies is restricted, with transactions conducted exclusively through authorized auctioneers. This makes the role of auctioneers crucial in price determination. This appears a case of principal-agent model, where the auctioneers act as the agents of the fishers (and buyers as well), and the agents have financial interests in the principals' (mainly fishers) operations.

The perishability of fish is a fundamental factor influencing its price fixation in the market. Being highly perishable, fish demands rapid and efficient handling from harvest to the consumer's table. The time-sensitive nature of fish requires careful consideration in pricing strategies. The shorter the time between catch and consumption, the higher the perceived freshness and quality, often resulting in elevated market prices. Market demand is the aggregate demand from wholesalers, export companies, fish sellers, retailers, and individual buyers at landing centers. Rather than demand, it's the supply that largely determine the market price as supply fluctuates widely in case of marine capture fisheries due to weather variability and sea conditions (Sathiadhas & Narayanakumar, 1994).

Fish market demand is relatively stable, though with an element of variation of prices within a day. The demand is higher in the mornings or evenings, depending on the timing of consumer markets. At times, retailers are willing to pay higher prices for fish in the morning without concern about increased fish availability at the end of the day. In fact, a fish market is quite different from a normal agricultural market. Farmers' markets have specific hours of operation. Though many fish landing centres have fixed time of operation, many ports/landing centres operate from morning to evening. Fishers operating from the same harbour or landing centre do not land their catch simultaneously, due to operational issues and infrastructure limitations. In such a situation, how can the auctioneer know the quantity of fish on a fishing vessel while it is still at sea?

The survey results indicate that communication plays a crucial role in both daily fishing operations and fish marketing, particularly in the context of price fixation. Beyond the conventional economic factors of demand and supply, the exchange of information between fishers and auctioneers significantly influences the pricing of this highly perishable commodity. About 86%

of respondents stated that fishers frequently communicate with the shore while fishing. On average, fishers communicate 2–3 times per trip with traders or merchants to discuss prices or marketing. Communication was most frequent and effective in Puthiyappa, particularly among mechanised trawlers followed by Vellayil and Chettuva (Table 1). Communication serves both operational purposes (fish availability, fishing grounds, accidents) and market purposes (traders/auctioneers contact). The primary purposes of this communication include informing other fishing groups about productive fishing locations, notifying auctioneers and traders about fish availability, and keeping in touch with family (Table 1).

The passing of supply information flow plays a major role in price determination and fish marketing, influencing the quantity sold, sale price, and timing of sales. Nearly 81% of respondents opined that communication with the landing centre significantly affects price fixation, highlighting its critical role in the marine fisheries marketing system. For instance, if sardine (supply) landings are very high at the landing center, auctioneers try to dispose of the product as quickly as possible at the available market rate. Conversely, when supply is low, they may withhold sales to secure better prices. Additionally, auctioneers coordinate with fishing operators about landing times, allowing for efficient handling and market planning. Thus, communication acts as a strategic tool in both operational decision-making and maximizing returns in the fish marketing chain. Since auctioneers' income is largely commission-based, higher fish prices result in higher commissions for the auctioneers. Moreover, since many auctioneers hold ownership stakes in fishing units, there is a strong incentive for them to maintain frequent communication with fishers at sea to receive updates on the catch. Respondents indicated that such communication was instrumental in determining sales and prices. The survey also revealed that, beyond interactions between fishers and auctioneers, fishers communicate with traders (wholesalers and retailers) as well. Further, auctioneers communicate with buyers (mostly whole salers) regarding market information on price, availability, and fish volume. This information is crucial for traders, commission agents of companies and exporters. These findings support Mebrate and Worku (2019), who noted that timely market information on price and quantity plays a key role in reducing the risk of financial loss in market transaction.

Table 1. Communication with the land for fish sale and the purpose of communication

| Centre (1) | Craft-gear combination (2) | Total number of trips in which communication was made with the land | Percentage of trips in which communication was made with the land (%) | Purpose of communication (%) | | | | | | | Positive opinion on the effectiveness of communi- cation in marketing of fish (%) |
|---------------------------|----------------------------------|---|---|--|----------------|---------------------------------------|------------------------------|--------------------------------|-----------|-----------------------------------|--|
| | | | | Fish availability to fellow fishers | Fishing ground | To contact auctioneers and traders | To inform about accidents | To contact family / friends | Any other | Mean number of times contacted | |
| Vellayil | Outboard gillnet | 219 | 100 | 43 | 14 | 43 | 0 | 0 | 0 | 2 | 83 |
| | Inboard ringseine | 66 | 98.5 | 50 | 0 | 50 | 0 | 0 | 0 | 2 | 100 |
| Puthiyappa | Outboard gillnet | 58 | 68 | 30 | 40 | 0 | 10 | 20 | 0 | 2 | 100 |
| | Inboard trawl net | 52 | 90 | 45 | 24 | 13.3 | 6.7 | 10.5 | 1 | 3 | 100 |
| | Mechanised trawlers | 19 | 100 | 36 | 19 | 28.3 | 11.3 | 5.7 | 0 | 5 | 100 |
| Chettuva Munakkakadavu | Inboard ringseine | 53 | 100 | 32 | 34 | 34 | 0 | 0 | 0 | 2 | 75 |
| | Mechanised Trawlers | 182 | 100 | 35 | 25 | 40 | 0 | 0 | 0 | 2 | 80 |
| Kollam | Outboard – Gillnet | 78 | 73 | 7 | 54 | 20 | 35 | 9 | 26 | 2 | 63.4 |
| | Outboard – Longline | 27 | 100 | 0 | 56 | 11 | 30 | 0 | 22 | 1 | 33.5 |
| | Outboard – Shore Seine | 27 | 100 | 0 | 75 | 0 | 19 | 0 | 3 | 1 | 45 |

Access to real-time market data through mobile phone and other digital platforms allow fishers to identify the most profitable markets, avoid distress sales, and negotiate more effectively with intermediaries. Mobile phones are the most popular means of communication among fishers, followed by wireless telephones and walkie-talkies (Figure 1). Mobile phone usage is limited to areas within 10–15 km of the coast due to signal availability. In contrast, fishers indicated that wireless communication devices can function 20–30 km offshore and are capable of transmitting messages over longer distances.

Walkie-talkie is most popular in the northern region of Kerala. Single-day fishers mostly used mobile phones, whereas multi-day and offshore fishers mostly used wireless and the walkie-talkie.

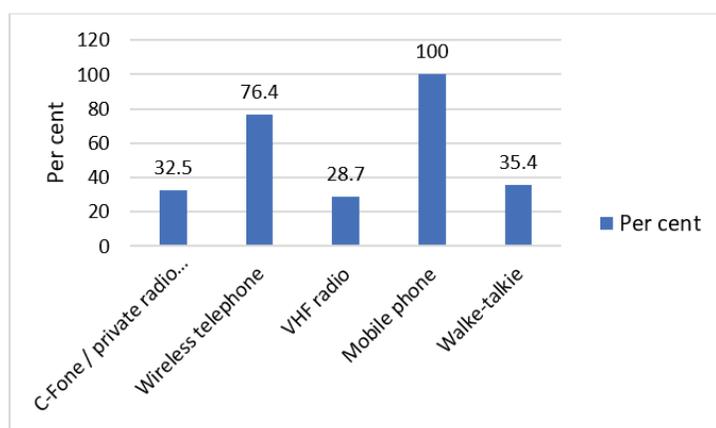


Figure 1. Most popular means of communication among fishers

Source: Primary Survey, 2024

Technological change in the fisheries sector has also brought remarkable improvements in communication. The communication pattern among stakeholders during the post-harvest phase plays a pivotal role in shaping domestic prices of fish products. Effective communication channels and practices among key players, including fishers, auctioneers, and other market intermediaries, are critical for disseminating timely and accurate information. Details regarding catch volumes, species composition, and overall quality of the harvested fish are essential for informed decision-making in the marketplace. Efficient communication has been facilitated through wireless technologies, including walkie-talkies, which enable real-time coordination. Transparent and efficient communication fosters coordination across the supply chain, enabling better anticipation of market demands and fluctuations. This exchange of information helps to optimize distribution logistics, manage storage facilities, and align pricing strategies with prevailing market conditions. Therefore, further development of effective communication system between the fisher at sea and the market intermediaries on the shore could help to attain better market integration, contribute to reduction in information asymmetry and help in pricing efficiency.

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