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ICAR - CENTRAL INSTITUTE OF FISHERIES TECHNOLOGY
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From the EDITOR'S DESK

In 2025, India's seafood industry is marked by record growth, strategic government support, and a strong focus on global market expansion, solidifying its status as a major world supplier. India achieved all-time high fish production (19.5 MMT) in 2024-25, becoming the world's second-largest producer. India's total seafood exports in 2024–25 reached $7.38 billion (₹60,523 crore), amounting to 1.78 million metric tonnes, with ambitious goals to double them by 2030. The number of export destinations expanded from 100 to 130 countries, with value-added product exports tripling to ₹7,666.38 crore signaling a shift towards high-end global markets. Coastal states like, Andhra Pradesh, Kerala, Maharashtra, Tamil Nadu and Gujarat, are the key players in seafood exports. Increased emphasis on sustainable fishing, aquaculture, and robust quality control is shaping the Seafood industry's future.

This issue of FISHTECH Reporter comprises ten articles covering a range of topics, from basic research 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, the use of secondary raw materials from fishery resources. The first two articles detail the prevalence of Microplastic pollution in fishing sector. Plastic litter accumulation from the Chinese dipnets operated at Munambam, Vembanad estuary, and the role of fishing gear as one of the significant contributor to microplastic debris in ocean, have been discussed in detail. 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 fish by-products and waste streams. These include fish protein hydrolysates, fish oil, collagen, gelatin, chitosan, and bioactive compounds. One of the articles elucidates the development of Spirulina hydrolysate and the formulation of Spirulina hydrolysate and collagen peptide composite as an antioxidant drink. Another article describes the utilization of fermented microalgae as a raw material for preparing beverages, offering the benefits of microalgal bioactive compounds.

From the EDITOR'S DESK

Post-harvest technology also emphasizes on improving the quality, safety, and shelf-life of fish products, while reducing waste and environmental impact. A study was carried out to assess the content of hypoxanthine and inosine as an index of spoilage for the temperature-abused Indian mackerel, thus, facilitating the prediction of the shelf life of fish. Another study was taken up to assess methods like depuration which have become essential strategies to improve the safety of shellfish for consumers against Endocrine Disrupting Chemicals (EDCs) in marine organisms such as mussels, oysters, clams and various fish species etc. Discussion on the mineral composition of wild and farmed Murrel fishes, that was determined using the microwave digestion method followed by analysis in ICP-OES, is detailed in the subsequent article. This edition also highlights the use of alternatives to traditional antibiotics, such as lytic bacteriophages, against Staphylococcus aureus, which has been considered a pathogen of "high priority" by the World Health Organization.

Lastly, two articles on social sciences have been presented in this issue. One of them deals with the socio-economic information that was collected from ethnic groups in WGH district of Meghalaya and the per capita fish consumption (PCFC) estimated for the region. Another study reveals the survey details on the issues (seasonal availability, price volatility, digital marketing and operational hurdles) in the online retailing sector in Ernakulam, Kerala. The innovative coping strategies employed by online retail vendors was also mentioned.

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 this editorial and the articles in this issue will stimulate further interest and research in this exciting area.

Contents

Plastic litter composition in Chinese dipnets: A case study from Munambam, Vembanad estuary

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Chinese dipnets are shore-operated liftnets along the estuaries and backwaters of Kerala locally known as *'Cheenavala'* or *'Kambavala'*. Chinese dipnets are one of the most common stationary fishing gears in the Vembanad estuary (Chandrasekar et al., 2020), which is the largest backwater system in Kerala, India. The Vembanad Lake opens to the Arabian Sea at two places; Kochi and Munambam. The Northern part of Vemabanad Lake opens into the sea at Munambam beach, which is subjected to continuous mixing of seawater and tidal activity due to its close proximity to the Arabian Sea. In Vembanad Lake, these nets are mainly operated along Munambam, Cherai, Kuzhupilly, Cheranellur, Koonammavu, Kadamakkudi, Ezhikkara, Mulavukad, Vypin, Fort Kochi, Edakochi, Arookkutty, Vaikom, Thannermukkam *etc*. There are 13 Chinese dipnets operating along the area near the Munambam beach (Figure 1). Chinese dipnets are operated on the principle of counter weight balance. The whole structure is supported by two pillars, and on the top of each pillar, a beam is placed horizontally. On the beam, two cantilevers are attached, forming an angle between them. The counter weighs approximately less than or equal to the weight of the outer cantilevers and the brass with attached net.

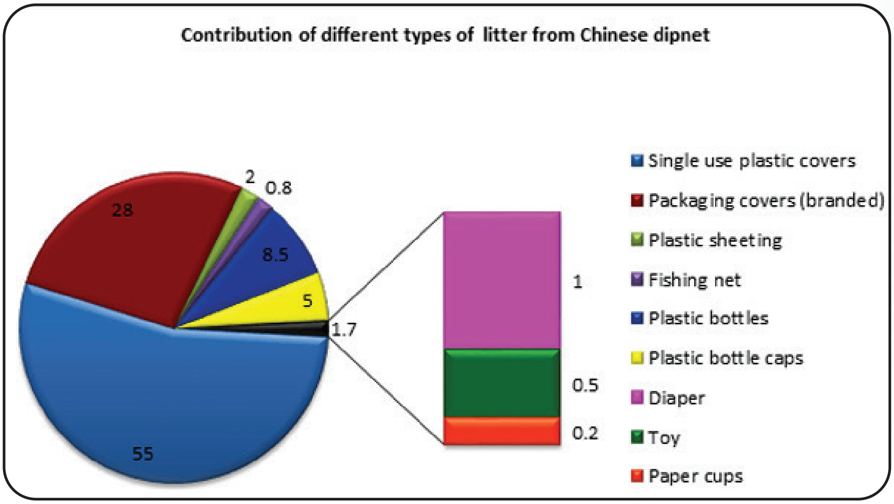
Figure 1. Chinese dipnets of Munambam

Prior to motorization of Chinese dipnets, the lifting and dipping operations were done by two or three persons manually by pulling the main rope together. Presently, the dipnets are completely motorized and operated by a single person. Different energy sources are used for the operation like; electricity, solar powered cells, and motorbike engine (refurbished bike of 100 cc engine ~ 10 hp) along with the pulling system. The gear is lifted up in 15- 20 minutes intervals. Majority of the gears are operated at a depth of 4-6 m. Small lantern/ LED lights (white or yellow) (15-100 watts) are attached at the center of the net to attract fish during night and early morning hours. The net is submerged in water for about 4-5 minutes before it is raised back by tugging ropes that are connected with the engine. After lifting the net, fishes are collected using a scoopnet (Pauly & Hridayanandan, 1991). Average catch may be around 3-7 kg/day/gear and is sold directly to the consumers at the landing centres (Figure 2). In Munambam, some of the fishers installed 2-3 cages adjacent to the dipnet, stocked with seabass (*Lates calcarifer*) and fed with trash fish like anchovies, shrimp, *Etroplus maculatus, Ambassis sp.* accumulated in the net (Dhiju et al., 2021).

Litter accumulation in Chinese dipnets

The Vembanad estuary acts as a direct channel for entry of pollutants into the Arabian Sea. Notably the estuary serves as a major drainage basin, receiving runoff from six major rivers (Achenkovil, Manimala, Meenachil, Muvattupuzha, Pamba and Periyar) flowing through some of the most urbanized regions of Kerala (John et al., 2020). Since, the Chinese dipnets are operated by dipping the net in water, it traps most of the floating and submerged plastic litters along with the fish catch. The litter encountered during Chinese dipnet operations can be either from river or estuarine runoff or from direct land runoff because they are operated near to the land area.

Plastic litter accumulation was recorded from all the Chinese dipnets (13 numbers) operated at Munambam (10.1789°N, 76.1697°E) during January – December, 2024. Based on the tide, the number of operations varies (high flow rate, low water level) even though 52 approximate operations were carried out by each dipnets per day. An average weight of 34.4 g/h/net of plastic litter was recorded during the study period (Figure 3). The most common categories of litter were single use plastic covers followed by plastic bottles, bottle caps, cups, sheets, toys, diapers, gloves, spoons, food containers etc. Fishing related plastics were less than 2% of the total plastics (polyethylene webbings, monofilament polyamide lines *etc.*).


Contribution of different types of litter from Chinese dipnet
28
2
0.8
8.5
5
1.7
55
1
0.5
0.2
Single use plastic covers
Packaging covers (branded)
Plastic sheeting
Fishing net
Plastic bottles
Plastic bottle caps
Diaper
Toy
Paper cups

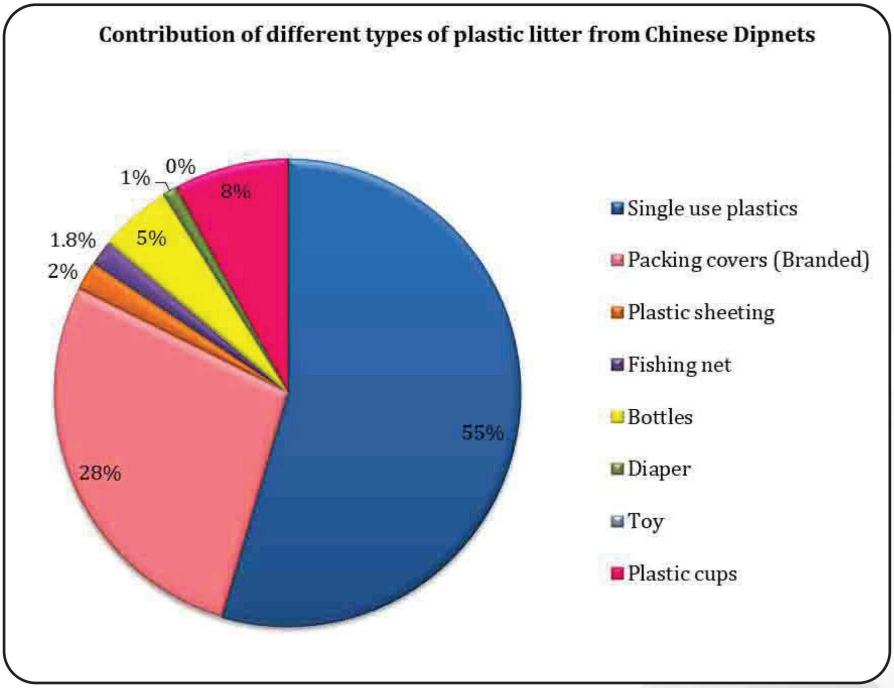

Contribution of different types of plastic litter from Chinese Dipnets
1%
0%
8%
1.8%
5%
2%
55%
28%
Single use plastics
Packing covers (Branded)
Plastic sheeting
Fishing net
Bottles
Diaper
Toy
Plastic cups

Figure 2. Fish catch from dipnets

Figure 3. Plastic litter collected from dipnets of Munambam, Ernakulam, Kerala

The accumulation of plastic in fishing gear creates substantial challenges for fishers, as single-use packaging materials often disrupt the operations leading to sorting difficulties, disposal issues and loss of fishing hours (Kripa et al., 2012; Shylaja et al., 2018). In response, ICAR-CIFT has installed many marine litter booths to collect retrieved plastics from fishing gears and also consistently raise awareness among fishermen about the detrimental impacts of plastic pollution. Additionally, the institute has initiated quantifying of plastic litter in selected fishing nets from both inland and marine sectors to develop a comprehensive database. This proactive approach not only highlights the severity of the issue but also aims to facilitate sustainable solutions, ensuring healthier marine ecosystems and more efficient fishing practices.

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Fishing gear material abrasion: An under recognized source of micro plastic pollution

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Abrasion of fishing gear materials occurs during fishing operations, leading to their wear and tear (Terry & Slater, 1998). For fishing gears like trawls, abrasion occurs while dragging along the seafloor. Another significant cause of abrasion is the onboard hauling equipment, hydraulic net haulers, or net drums. Gillnets are subjected to wear and tear while setting, hauling, and during contact with seabed. Abrasion is most common and significant for fishing ropes. Commonly used fishing ropes are made up of different plastics, such as polyethylene (PE), polypropylene (PP), and polyamide (PA). Abrasion of these synthetic ropes can occur both internally (contact between yarns of the same rope) and externally (contact between rope and another surface) (Mandell, 1987). During fishing operations, there is a considerable amount of strain, abrasion, and friction between these ropes and various surfaces that they interact with. Ropes can be abraded from continuously being run through hauling machines as well as with hard surfaces like fibre glass, wood, and metal on fishing vessels (Grimaldo et al., 2019). The wear and tear of plastic ropes used during commercial fishing can be substantial, particularly when they come in contact with the seafloor.

Fishing gear is known to be a significant contributor to the number of plastic fragments in the sea, and about 18% of all plastic debris in the ocean is estimated to occur from the fishing industry (Andrady, 2011). Much of this plastic arises from abandoned, lost, or otherwise discarded fishing gear (ALDFG) (Macfadyen et al., 2009). Approximately 200 tonnes of microplastics are released annually from fishing gear in Norwegian commercial fisheries (Syversen et al., 2020). However, few studies have documented the proportion of marine microplastics that comes from fishing gear used for active fishing. Fishing rope has been identified as a common form of macro litter in the marine environment, and only a few studies have examined its fragmentation into microplastics during its use (Nelms et al., 2017). These fishing ropes are likely to fragment not just when they are lost, but also while they are being used actively due to the high level of abrasion that occurs during fishing. This abrasive action may directly cause the formation of microplastics. In addition to the gradual abrasion, these plastic ropes also get fragmented by other causes like UV radiation. While ALDFG has garnered increasing attention as a contributor to macroplastic pollution, the generation of microplastics from direct use in fishing and other maritime activities is also a cause for concern.

Common ways to measure the effect of abrasion are either weighing to establish reduced mass or tensile testing to establish reduced tensile strength. However, it is difficult to estimate the abrasion tolerance during actual fishing operations. Mostly simulation studies are carried out in the abrasion testing machines (Heidi et al., 2023; Jalal et al., 2024). A study was conducted in ICAR-CIFT, Kochi on the abrasion tolerance of polypropylene (PP) twine (twisted twine 3 ply; diameter 2.5±0.017 mm), which is commonly used as head rope and foot rope of gillnets. These twines were subjected to controlled application of wear (Standard atmospheric conditions of temperature 25±2°C and humidity 65±2%) in the laboratory in Abrasion testing Machine (Model 300mm Stroke) which is having an abrading surface on a rolling drum (knurling roller with stainless steel surface having diameter 270 mm and 330 mm width with diamond knurling; rotation speed: 10 rotations/min; weight of 60 g attached to loose end of twines to provide standard pretension) and simulate the abrasion condition during setting and hauling of nets (Figure 1). After this controlled application of abrasion, the breaking strength of each sample was measured and compared to the strength of control (non-abraded) samples (ISO 4649 / DIN 53516; IS 5815 (Part4): 2018 (Reaffirmed 2016) (Figure 2a and 2b). The abraded particles were also collected and observed under Leica MZ16A stereo microscope at 25X magnification (Figure 3). After 4 lakh cycles (600 hrs) of abrasion, the breaking strength (509.31±46.37 N) of abraded twines declined to below 50% when compared with the breaking strength of the control sample (1077.32±24.75 N). The weight of the abraded samples (final weight 6.22±0.10g) also declined compared to the control sample (initial weight 6.47±0.09g), which indicates that much amount of weight (4.01%) are released as fragments including microplastics (size range 0.20 mm to 3.51 mm).

Figure 1. Yarn abrasion testing machine

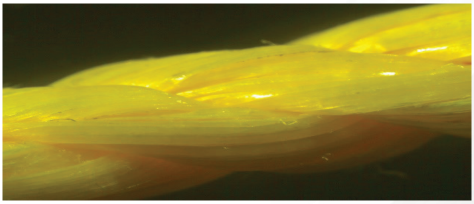

Figure 2a. Non-abraded PP twine

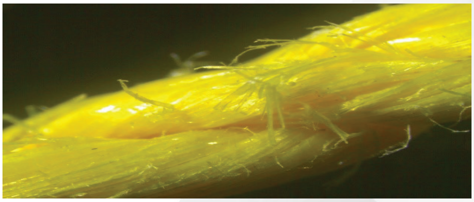

Figure 2b. Abraded PP twine

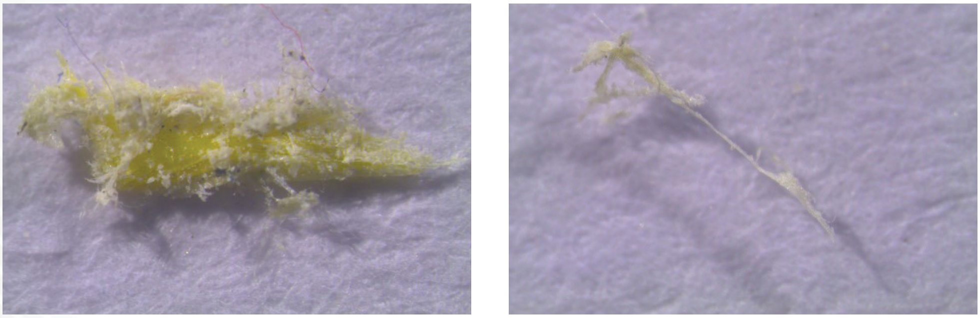

Figure 3. Microscopic images of microplastics from abraded PP twines (25X magnification)

Studies on abrasions of different commercial rope materials having varying diameters will be required to analyse the abrasion resistance and corresponding microplastic fragmentation from these materials. Preventive measures such as the selection of materials with increased tolerance to wear, replacing the older/damaged materials, use of thicker fibres will reduce the abrasion of fishing gear materials and further microplastic release into the aquatic environment. Incorporation of biodegradable twines in fishing gears will also lessen the amount of microplastic generation from fishing gears. Further studies are needed to evaluate the abrasion of fishing gear materials during actual fishing operations.

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Development of Spirulina hydrolysate and fish scale collagen peptide composite and its characterization

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Spirulina (*Spirulina platensis*) is rich in protein, vitamins, minerals and essential fatty acids. Additionally, it has plenty of antioxidants. The hydrolysed proteins tend to exhibit various functional activities such as antioxidant, antihypertensive, antimicrobial, anticarcinogenic activity, etc. (Chalamaiah et al., 2012). Hydrolysates of spirulina protein have been shown to have strong antioxidant activity, as well as a range of potentially beneficial health effects. Collagen peptide is a hydrolyzed form of collagen or gelatin with a molecular weight in the range of 1–5 kDa and has great potential in the pharmaceutical, health food, nutraceutical, and cosmetic industry (Asserin et al., 2015). Fish-derived collagen peptides have been found to have noticeable antioxidant amino acids. Apart from that, the collagen peptides are shown to promote the absorption of vitamins and minerals. However, incorporation of peptides into food products leads to major challenges, such as their stability during processing, undesirable taste, and loss of functionality in the targeted delivery site. There is a market for combined formulations of the collagen peptide with minerals and vitamins. The present study was aimed to prepare protein hydrolysate from Spirulina and to evaluate its properties. Yet another objective was and to formulate Spirulina hydrolysate and collagen peptide composite and evaluate its acceptability as an antioxidant drink.

The commercial Spirulina powder was procured from Oferr Nallyan, Chennai, and the hydrolysate was prepared by using 1.0% (w/w) papain enzyme and spray dried (Figure 1a & 1b). The commercial fish scale collagen peptide was procured from Athos Collagen Pvt. Ltd., Gujarat. The physico-chemical, amino acid composition, and the antioxidant properties of spirulina (SP), spirulina hydrolsate (SPH) and collagen peptide (CP) were analyzed.

Figure 1a. *Spirulina platensis* powder

Figure 1b. Spirulina hydrolysate powder

The proximate composition revealed that the collagen peptide had higher protein content, followed by spirulina hydrolysate than the crude Spirulina (Table 1). Generally, the hydrolysed products will have higher protein content because during hydrolysis proteins get solubilized and other insoluble material will be removed.

Table 1: Proximate composition of Spirulina, Spirulina hydrolysate and Collagen peptide

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Spirulina (SP)	8.75±0.25	59.28±0.02	5.80±0.01	6.95±0.03
Spirulina hydro-lysate (SPH)	5.88±0.40	78.45±0.01	1.52±0.01	10.85±0.01
Collagen peptide (CP)	3.95±0.20	92.15±0.02	0.5±0.02	1.6±0.03

The amino acid composition revealed a significant presence of essential and non-essential amino acids in all the samples. The major amino acids present in both SP and SPH were arginine, leucine, isoleucine, valine, threonine, lysine, tyrosine, alanine, aspartic acid and glutamic acid. The major amino acids present in the CP include arginine, lysine, valine, alanine, aspartic acid, glycine, glutamic acid, proline and serine. Antioxidant activity measured by DPPH assay revealed SPH had the highest antioxidant activity (78.24%) than others (SP-68.84%; CP-38.80%). Colour analysis showed that the highest L^* value for CP (94.74) followed by SPH (71.91) and spirulina (38.57). In the present study, eleven different spirulina hydrolysate and collagen peptide (CP) composites were prepared and their physicochemical properties evaluated. Based on its protein content and antioxidant activity, three formulations were selected, and their sensory analysis was carried out. (Table 2). The higher antioxidant activity in spirulina hydrolysate and collagen peptide composite might be due to the availability of higher amino groups for donating electrons to DPPH radicals. However, the antioxidant activity of SPH and CP composite did not follow a linear trend. DPPH activity decreases with increasing concentration primarily due to saturation, nonlinear response and potential interactions that hinder effective radical neutralisation. The antioxidant activity pattern of the peptide matrix from two different origins has not been investigated so far. The present study forms the preliminary investigation in this line that needs further investigation on spirulina hydrolysate and collagen peptide matrix behaviour in the food system. For sensory evaluation, spirulina hydrolysate and collagen peptide composite (1.5%) were dissolved in warm water and presented to the panellists to evaluate its acceptance as an antioxidant drink. The sensory evaluation revealed that the composite contained SPH and CP in the ratio of 0.6:1.4 had higher acceptability as an antioxidant drink. The collective findings from the study emphasized that Spirulina hydrolysate and collagen peptide composites have the potential to enhance nutritional and antioxidant properties in food products like soup, and bakery products.

Table 2: Protein content, antioxidant activity and sensory analysis of selected SPH and CP composite

Sample	Protein (%)	Antioxidant activity (%)	Appear-ance	Flavour	Taste	Overall acceptability
A	88.65± 0.02	82.38±0.40	7.6±0.40	6.6±0.20	7.3±0.20	7.3±0.35
B	83.95±0.05	79.69±0.35	6.6±0.55	6.8 ±0.35	6.3±0.35	6.6±0.20
C	73.69±0.10	64.12±0.45	6.0±0.50	7.0±0.15	5.6±0.40	6.3±0.40
D	59.28±0.02	68.84±0.25	6.3±0.25	5.6±0.50	5.3±0.50	5.3±0.35

where, A=0.6:1.4 (SPH:CP); B=1:1(SPH:CP); C=1.4:0.6 (SPH:CP); D=Raw spirulina powder

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Microalgal fermentation by microbes: A powerful approach to bioactive compound extraction

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Fermentation is one of the oldest food preservation methods, and recently, fermentation has been used as a biological tool to liberate bioactive compounds trapped in food matrices. Fermentation has potential applications in the extraction of valuable compounds from an array of resources ranging from agro-industrial waste to microalgae. Lactic acid producing bacteria of the genus *Lactobacillus,* owing to their metabolic flexibility and biosynthetic ability, are extensively used for fermentation in the food industry. Foods fermented by *Lactobacillus* spp. have beneficial health effects as the bacteria produce various compounds including antioxidants, antimicrobial compounds, vitamins, organic acids, phenols, polysaccharides, *etc*. Consequently, lactic acid fermentation enjoys a wide spectrum of applications in the food, beverages, cosmetics and pharmaceutical industries. Consumer preference for microalgae-based foods is increasing as they are perceived to be a vegetarian source of omega-3 fatty acids, free amino acids, polypeptides, soluble fibre, bioactive pigments, polysaccharides, vitamins, minerals, antioxidants, *etc*. Fermentation of microalgae is a viable approach to release these bioactive molecules from the cytoplasm. In the present work, a process for the fermentation of microalgae, *Nannochloropsis gaditana* using *Lactobacillus plantarum* was standardized.

The objective of the study was to utilize fermented microalgae as a raw material for beverage preparation by the submerged fermentation method. For this, fresh biomass of *N. gaditana* was fermented in normal saline by adding *L. plantarum* culture. Two sources of fermentable sugar, a monosaccharide (glucose) and a disaccharide (lactose), were added at varying concentrations to enhance the fermentation process. The reduction in pH during incubation at 35°C was monitored to determine the progress of fermentation.

Table 1. Changes in pH during fermentation of microalgae (*N. gaditana*) with *L. plantarum* culture

Sample	No sugar		Lactose supplementation					Glucose supplementation				
	C1	C2	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
pH at 0 h	7.08	7.12	7.12	7.12	7.12	7.12	7.12	7.12	7.12	7.12	7.12	7.12
pH after 24 h	7.08	6.65	6.16	4.18	3.78	3.65	3.57	3.70	3.22	3.24	3.21	3.25
pH at 48 h	7.06	6.70	6.04	3.26	3.37	3.30	3.27	3.68	3.19	3.18	3.16	3.15

C1 & C2 are control samples, C1 contains only microalgae and normal saline and C2 contains microalgae and *L. plantarum* culture. T1-T5 are samples containing algae, *L. plantarum* culture and lactose at varying concentrations from 0.125%, 0.25%, 0.5%, 1% and 2%. T6 to T10 are samples containing algae, *L. plantarum* culture and glucose at varying concentrations from 0.125%, 0.25%, 0.5%, 1% and 2%.

It was found that 24 h fermentation was sufficient to reduce the pH to below 4 (Table 1). The reduction in pH or the progression of fermentation depended on the source and concentration of sugar added. Being a monosaccharide, fermentation in the presence of glucose resulted in a faster reduction of pH compared to that of lactose, which is a disaccharide.

Phenolic content and reducing power of C1, C2, and samples fermented with the lowest and highest concentrations of both the sugars (T1, T5, T6 and T10) were evaluated (Table 2). Fermented samples showed higher amounts of phenolic compounds and reducing power values compared to the control, indicating that fermentation has aided in the release of antioxidants from the microalgae.

Table 2. Phenolic content and Reducing Power of control and fermented samples

Sample	C1	C2	T1	T5	T6	T10
Total phenolic content (μg Eqwt. GA/ml)	33.45	55.85	81.85	73.28	88.57	86.14
Reducing power (abs)	0.298	0.306	0.549	0.565	0.476	0.491

Even though glucose aids in faster fermentation, lactose sugar was selected in light of the low acidity that is suitable for product development. Based on the results, the fermentation of microalgae with 0.5% lactose sugar in normal saline for 24 h was optimized for fermenting *N. gaditana*.

Further studies were conducted to confirm whether the reduction in pH is caused by the fermentation of sugar or the fermentation of algae. For this, the algal fermentation was carried out with and without sugar. A sample of sugar alone was also fermented for comparison. Reduction in pH after 24h fermentation process, lactic acid content, reducing power, and total phenolic activity of the fermented samples were determined.

Table 3. Fermentation of microalgae with and without sugar

Sample	**C1**	**C2**	**T1**	**T2**
pH after 24 h	6.69	5.67	4.66	3.48
Lactic acid content (mg/100 ml)	9.0	18.4	63	65
Total phenolic content (μg Eqwt. GA/ml)	17.14	Nil	30.14	44.14
Reducing power	0.044	0.077	0.081	0.095
DPPH scavenging activity (%)	17.6	12.6	46.6	32.6

C1 =1% microalgae in normal saline with 0.5% lactose

C2 = no microalgae but 0.5% lactose in normal saline with 0.1% culture

T1=1% microalgae in normal saline with 0.5% lactose and 0.1% culture

T2= 1% microalgae in normal saline with 0.5% lactose with 1% culture

These experiments (as shown in Table 3) have proven that the reduction in pH was contributed by the fermentation of microalgae, as the pH of T1 and T2 samples, which contained both microalgae and *L. plantarum* culture, was markedly lower than C1 and C2, which contained microalgae plus lactose and lactose plus *L. plantarum* culture, respectively. In addition, the phenolic content and antioxidant activities of samples containing microalgae and *L. plantarum* culture were significantly higher than the control samples. These findings confirmed the release of antioxidant compounds from microalgae through fermentation with *L. plantarum* bacteria.

The findings of the study suggest that the marine microalgae, N. gaditana can be fermented using *L. plantarum* bacteria with the supplementation of sugar for extracting biomolecules. Since microalgae are considered as a novel source of valuable bioactive compounds, the findings of the study will benefit the food industry by advancing bioactive extraction and applications.

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Formation of hypoxanthine and inosine as indicators of nucleotide degradation in Indian mackerel during temperature abuse

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There is a huge demand for Indian mackerel among fish consumers owing to its taste and nutrient content, especially polyunsaturated fatty acids. Autolytic breakdown of nucleotide, adenosine triphosphate (ATP), leads to the formation of adenosine diphosphate (ADP), adenosine monophosphate (AMP), inosine monophosphate (IMP), and the accumulation of hypoxanthine (Hx) and inosine (HxR). Hypoxanthine is associated with the progressive loss of desirable fresh fish flavor (Özoğul and Özogul, 2002) and accumulates with the advancement of storage time and the development of bitter taste. Therefore, the freshness of fish can be readily determined based on the Hx concentration.

A study was carried out to assess the formation of hypoxanthine and inosine during temperature abuse of Indian mackerel, *Rastrelliger kanagurta*. Freshly collected Indian mackerel were subjected to temperature abuse by storing at room temperature (~30°C) to evaluate the formation of hypoxanthine and inosine (Figure 5). The study also evaluated the formation of Hx and HxR during iced storage of the Indian mackerel as a control. The biochemical changes of quality such as pH, TVBN, TMA and K value were evaluated along with changes in Aerobic Plate Count (APC), psychrophilic count, H_2S formers and *Pseudomonas*. The temperature-abused samples were drawn at 0, 4, 6 and 8 hours and after overnight storage.

At 0 hour, the content of hypoxanthine and inosine were 49.27±1.92 and 34.85±1.82 mg/Kg and increased to 151.66±5.3 and 83.55±2.9 mg/Kg, respectively after 8 hours of storage. After overnight storage, the hypoxanthine and inosine reached 186.04±1.14 and 0.19±0.03 mg/Kg, respectively as inosine is degraded to hypoxanthine by temperature abuse. During iced storage, the hypoxanthine and inosine reached 55.32±2.29 and 38.15±3.9 mg/Kg, respectively after 24 hours. The initial K value was 27.62±0.06% and it crossed the spoilage limit of 60% (Lakshmanan, 2000) at 8^{th} hour of storage (86.18±0.9%). The results of the present study are shown in Figures 1 to 4.

The pH of meat increased from 6.04±0.01 to 6.46±0 at 8^{th} hour of storage and 7.37±0.08 after overnight storage, whereas the pH of mackerel after overnight iced storage was 6.15±0.01.

At 0^{th} hour, TVBN and TMA was 11.2 and 0 mg%, respectively, and it increased to 32.2±1.97 and 7±0 mg%, respectively, after 8 hours of storage, while that of ice-stored Indian mackerel for 24 hours was 14±0 and 0 mg%, respectively. The APC at 0^{th} hour was 4.59 log CFU/g and it crossed the spoilage level of 7 log CFU/g at 8^{th} hour of storage (7.15 log CFU/g) and reached 8.45 log CFU/g after overnight temperature abuse, while that of ice stored Indian mackerel for 24 hours was 3.94 log CFU/g. *Pseudomonas* count increased from 2.6 to 4.18 log CFU/g after overnight temperature abuse and H_2S formers increased from 2.3 to 6.77 after overnight temperature abuse of Indian mackerel. At 0^{th} hour, psychrophilic count was 4.26 log CFU/g and crossed 7 log CFU/g after overnight temperature abuse (7.88 log CFU/g).

Ozogul et al., (2007) reported the hypoxanthine content as a freshness indicator for sardine stored under the modified atmosphere package and vacuum package. The presence of hypoxanthine seriously brings down the quality and flavor of fish products (Li et al., 2022). The present study concludes that the temperature abuse of the Indian mackerel accelerated the spoilage of samples and the elevated content of hypoxanthine clearly reflected the spoilage level in comparison to the results based on the biochemical and microbiological parameters. Hence, the content of the hypoxanthine can be taken as an index of spoilage for the temperature-abused Indian mackerel and it can be used for predicting the shelf life of fish.

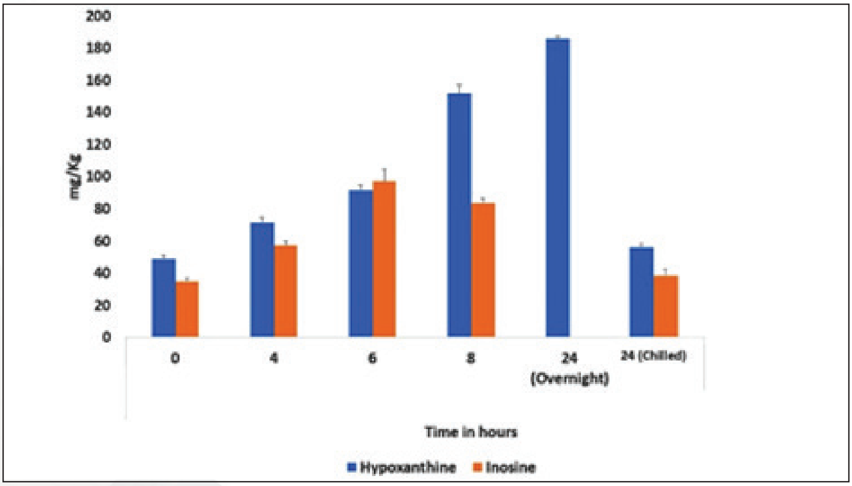

Figure 1. Changes in hypoxanthine and inosine content of Mackerel that was temperature abused

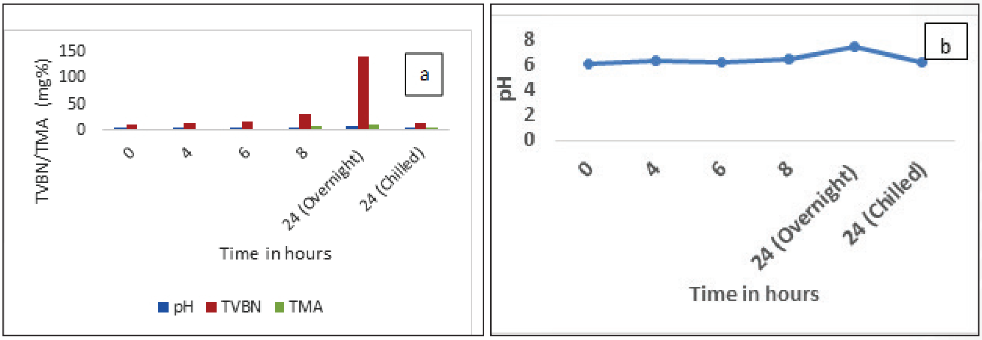

Figure 2. Changes in a) TMA and TVBN and b) pH

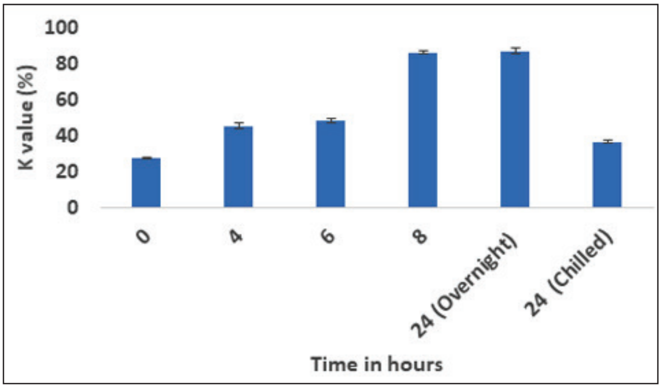

Figure 3. Changes in K value

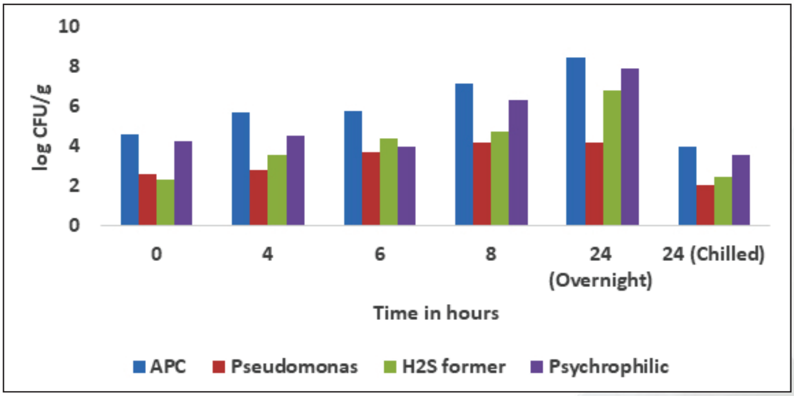

Figure 4. Changes in Aerobic Plate count, Pseudomonas, H_2S formers and Psychrophiles

Figure 5. Fresh and Temperature-abused Indian mackerel

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Prevalence Effect of depuration on endocrine-disrupting chemicals in black clams (*Villorita cyprinoides*) from Vembanad Lake

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Endocrine-disrupting chemicals (EDC) have been demonstrated to disrupt hormonal functions, homeostasis, and developmental processes, adversely impacting organisms and their offspring. These chemicals exert their deleterious effects by either mimicking natural hormones or by disrupting hormone receptor signaling pathways (Kassotis et al., 2020). EDCs, including pesticides, industrial chemicals, and additives, pervade natural ecosystems due to anthropogenic activities, posing significant health risks. Extensive research has focused on their accumulation in marine organisms such as mussels, oysters, clams, and various fish species over recent decades (Bagde et al., 2023). Urbanization, industrialization, and population growth have increased pollution in coastal and estuarine ecosystems. Industrial effluents, sewage, runoff, landfill leachates, maritime activities, and atmospheric deposition have elevated EDCs and other pollutants, causing bioaccumulation in organisms like mollusks. Bivalve mollusks, such as clams, are crucial ecological filter feeders and bioaccumulators, leading to the accumulation of contaminants, making them sensitive indicators of environmental pollution and potential vectors for transferring contaminants up the food chain to humans (Anjana et al., 2021).

In 2020, India's clam production reached 1,07,559 tons, with the black clam (*Villorita cyprinoides*) being the most significant species. Kerala was the top contributor, accounting for 73.3% of the total production, while Vembanad Lake emerged as the leading producer, contributing 93% of the harvest (CMFRI, 2021). The region relies heavily on clam harvesting for economic survival, making it crucial to ensure the safety of shellfish for human consumption. However, increasing environmental pollution presents significant challenges to achieving this goal. The best way to reduce contamination risks is to grow or harvest shellfish in clean or minimally polluted waters. Unfortunately, such pristine environments are becoming rare due to increasing human activities. Therefore, methods like depuration have become essential strategies to improve the safety of shellfish for consumers (Anjana et al., 2021). Depuration, an established purification process, entails subjecting harvested shellfish to controlled clean-water systems for a specified duration to facilitate the expulsion of accumulated contaminants (Bi et al., 2023). This procedural step aims to attenuate the levels of pathogens, biotoxins, heavy metals, and EDCs, thereby mitigating health risks associated with shellfish consumption. Empirical evidence derived primarily from studies conducted in Western countries, including the United States and the European Union, underscores the efficacy of depuration in reducing bacterial loads and mitigating heavy metal concentrations in bivalve mollusks. However, despite numerous studies confirming reductions in bacterial and heavy metal contamination (Anjana et al., 2021; Chinnadurai et al., 2021), there is limited research on the effects of depuration on EDC levels in clams. EDCs, known to interfere with hormonal regulation, are associated with adverse health outcomes such as reproductive disorders, metabolic and cardiovascular diseases, neurodevelopmental deficits, and compromised immune function. Specifically, these chemicals are linked to infertility, hormone-sensitive cancers (*e.g.,* breast and prostate cancer), obesity, diabetes, and an increased risk of cardiovascular conditions like hypertension, while early-life exposure may result in developmental abnormalities, cognitive impairments, and heightened susceptibility to infections and autoimmune diseases. In this context, the present study investigated alterations in EDC levels within black clams (*V. cyprinoides*) sourced from diverse estuarine locales within Vembanad Lake, both pre- and post-depuration.

Clams were collected from the estuarine regions of Vembanad Lake both before and after the depuration process for analysis. Raw clam samples (n=40) were obtained from local sellers at Perumbalam Island in the Alappuzha district of Kerala, India, while the depurated samples (n=40), subjected to a 24-hour purification process, were sourced from the clam processing facility established by ICAR-Central Institute of Fisheries Technology, Cochin, on the same island. Samples were extracted using protocols adapted from established methodologies for fatty fish analysis, with tailored adjustments for clam tissues (Nazar et al., 2023). Briefly, extraction was done with acidified acetonitrile followed by salting out using a QuEChERS pack. The resulting supernatant was subjected to a two-stage cleanup process: first with $CaCl_2$ and then with dSPE sorbents. The final supernatant was evaporated and reconstituted in ethyl acetate. The filtered extract was then analyzed using Gas Chromatography Tandem Mass Spectrometry (GC-MS/MS).

Examination of non-depurated clam samples revealed alarmingly elevated levels of EDC contamination in 56.21% of collected samples, with 2-phenyl phenol emerging as the predominant contaminant detected within concentrations ranging from 5.01 to 45.01 ng/g in 43.01% of samples. Bisphenol A and DDTs were also identified as noteworthy contaminants. Figure 1 elucidates the distribution and concentration profiles of EDC contamination within the clam matrix, underscoring the prevalence of polycyclic aromatic hydrocarbons (PAHs) as the most frequently detected chemical group (64.90% of samples) followed by organochlorine pesticides (OCPs, 29.25%). Comparative analysis between depurated and non-depurated clam samples unequivocally demonstrated significant reductions in EDC concentrations after a standardized 24-hour depuration regimen. Overall, the depuration process resulted in a significant reduction (90.1%) in total EDC concentrations within the clam matrix. This substantive reduction is attributable to the physical expulsion of gut contents during depuration, thereby diminishing the bioavailability of contaminants (Chinnadurai et al., 2023). The initial mean concentration of 2-phenyl phenol (11.72 ng/g) significantly decreased to 2.21 ng/g (<LOQ) following the depuration process. A similar reduction was observed for Bisphenol A, with concentrations declining from 42.47 ng/g to 1.89 ng/g (<LOQ). This consistent reduction in EDC levels after depuration further substantiates the effectiveness of the process in cleansing clam tissues, as illustrated in Figure 2. However, since contaminants may accumulate in the post-depuration water, it is recommended to implement advanced treatment methods like activated carbon filtration, advanced oxidation processes (*e.g.,* UV/H_2O_2), or electrochemical treatment to ensure thorough removal and prevent environmental contamination.

Elevated EDC levels in non-depurated black clam samples from the Vembanad estuary pose significant threats to both aquatic ecosystems and human health. Local communities dependent on clam harvesting are particularly vulnerable, with risks exacerbated by urbanization and tourism. Consumers of contaminated bivalve mollusks face potential health hazards from EDCs. Systematic depuration is crucial for mitigating these risks, as it reduces EDC levels and addresses contamination from pathogens and heavy metals, aligning with international food safety standards. Our findings highlight the role of depuration in significantly reducing EDC concentrations, underscoring its importance as a safeguard before consumption. In conclusion, advancing depuration in bivalve processing and regulations is essential for supporting sustainable aquaculture, protecting marine ecosystems, and ensuring public health. Continued research into depuration's effectiveness in different environments and its potential to mitigate anthropogenic pollution impacts is crucial. Depuration remains pivotal for reducing EDC contamination in shellfish, promoting safer seafood consumption, and fostering environmental sustainability in the face of ongoing anthropogenic challenges. To enhance depuration practices, it is essential to raise awareness among fishermen about the health risks associated with consuming and selling non-depurated clams through educational programs, community engagement, and media outreach. Providing financial support for affordable depuration units, offering hands-on training, and implementing certification schemes can further encourage the adoption of these practices. Additionally, promoting depurated clams as a safer, higher-value product can increase consumer demand, ensuring both public health protection and economic benefits for local fishermen.

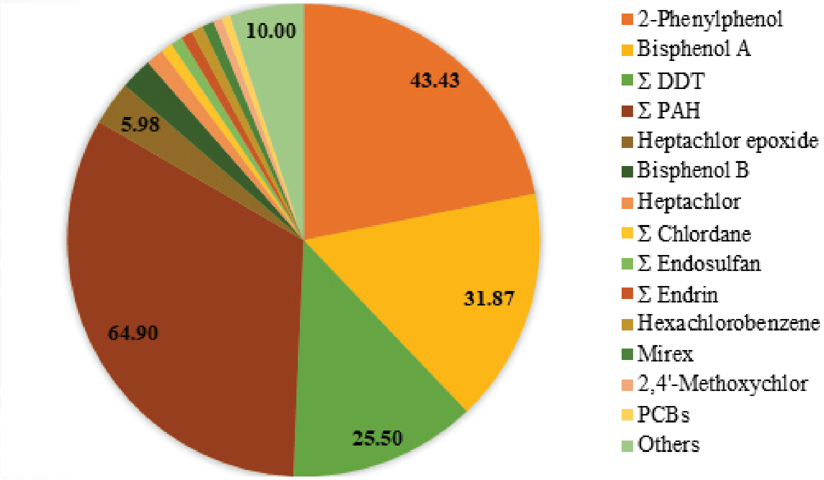

Figure 1. Distribution of EDCs (in %) in non-depurated black clams collected from the Vembanad estuary

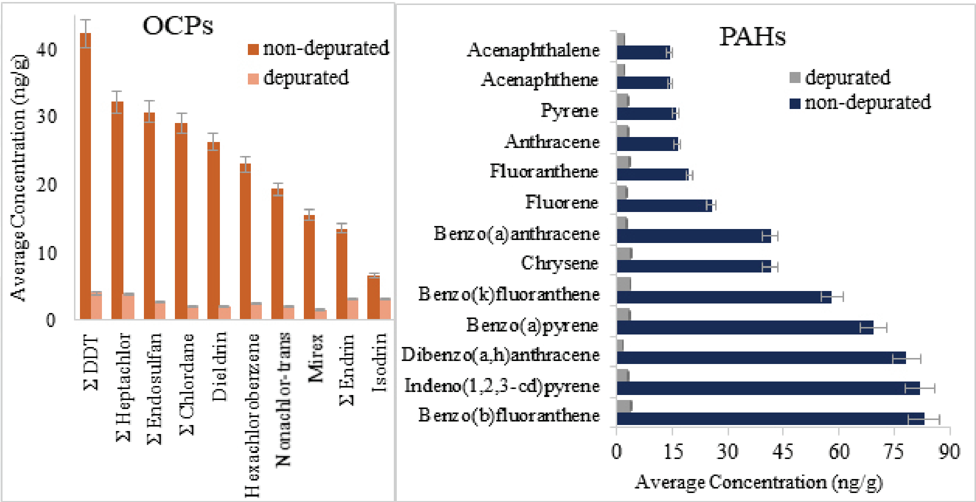

Figure 2. Changes in the concentration levels of EDCs, including (a) OCPs and (b) PAHs in the clam matrix before and after depuration

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Mineral Composition of Wild and Farmed Murrel Fishes

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Murrels, commonly known as snakeheads (*Channa striata*), obtain higher market value among the freshwater fishes due to their taste as well as their medicinal and therapeutic value. Consumer demand is also driven by its lower fat content, high protein content, and minimal intramuscular spines. Being air breathers and able to survive in water bodies with low dissolved oxygen, the murrels are one of the emerging species of culture in the biofloc system, preferred over most hardy fish, tilapia. Air-breathing fish, such as murrels, account for about 13% of the freshwater fish marketed in India. In the present study, the mineral composition of both wild caught and farmed (biofloc) murrel fishes (Figure 1a & 1b) was determined using the microwave digestion method followed by analysis in ICP-OES (iCAP 6300 Duo, Thermo Fisher Scientific). Since the murrel skin is reported to have more therapeutic value than muscle, both the muscle and skin were compared to know the variation in elemental composition. The data were subjected to one-way ANOVA and the means were compared using Tukey's HSD test using IBM SPSS Statistics (version 30.0.0. (172)). The significant level was identified at P value ≤ 0.05

Compared to wild-caught murrel fish, farmed fish muscle was found to have higher potassium (K) and phosphorous (P) content (Table 1). The potassium content was found to be 2292.86 ± 167.83 mg/Kg and 2580.61 ± 43.33 mg/Kg, respectively, in the muscle of wild and farmed murrel, while the phosphorous content was found to be 2978.94 ± 109.86 mg/kg and 3246.58 ± 169.18 mg/Kg, respectively. For Calcium (Ca) and magnesium (Mg) also farmed fish muscle were found to have higher content (Ca-289.93 ± 127.62 mg/Kg, Mg-345.76 ± 18.28 mg/Kg) than wild-caught murrel fish (Ca-239.71 ± 57.09 mg/Kg, Mg-311.43 ± 10.49 mg/Kg). While for sodium content, wild-caught fish had comparatively higher concentration (225.70 ± 6.01 mg/Kg) than farmed fish (190.18 ± 6.37).

Among the trace elements analyzed, iron (Fe) and zinc (Zn) content was significantly higher in the muscle of farmed fish than the muscle of wild caught. Iron content was 3.47 ± 1.87 mg/Kg in wild-caught fish muscle and 15.21 ± 1.30 mg/Kg in farmed fish muscle. Zinc content was 1.67±1.03 mg/Kg in wild-caught fish muscle and 6.39±0.45 mg/Kg in farmed fish muscle. Similar results for microminerals were also reported by Laoli et al. (2023) and Mustafa et al. (2013) for *Channa striata* found in Indonesian waters.

In the case of fish skin, wild-caught murrel skin was found to have a higher content of macroelements such as calcium (3393.00±1.64 mg/Kg), potassium (2024.00±2.73 mg/Kg), phosphorous (7069.00±1.56 mg/Kg) and magnesium (404.90±4.69 mg/Kg) as well as the trace element manganese (3.35±5.43 mg/Kg) than farmed fish skin. In the case of trace elements, farmed murrel skin was found to have a higher concentration of iron (18.84±4.65 mg/Kg), zinc (46.61±2.74 mg/Kg), and copper (1.42±1.58 mg/Kg) than the wild-caught fish.

The results demonstrate that the biofloc-farmed murrel fish that were found have higher content of essential micronutrients, especially zinc and iron content, than the wild-caught fish. The murrel fish were reported to have high therapeutic values, *viz.,* wound healing and anti-inflammatory properties, presumably due to higher albumin and zinc content (Laoli et al., 2023; Mustafa et al., 2012, Mustafa et al., 2013; Suprayinto et al., 2013). The zinc plays a pivotal role in the immune system, including the maintenance of skin and mucosal barrier integrity, development and function of immune cells, production of antibodies, and coordination of immune responses against pathogens. The higher content of iron supports a healthy immune system, regulation of hemoglobin in red blood cells, DNA synthesis, and energy metabolism (Afriani et al., 2020; Budiyarti & Mahda, 2023; Dewita et al., 2022; Herawati & Allawiyana, 2023).

The study demonstrates significant variations in the mineral content of wild and farmed murrel fish skin. The muscle of farmed fish has higher mineral content than that of wild-caught fish for K, P, Fe, Se, and Zn. A similar pattern of mineral content was observed for Ca, Mg, Cu, and Mn in both wild-caught and farmed fish muscles. According to the Food Safety and Standards Authority of India, the recommended dietary allowances (RDA) for minerals per day for healthy adult Indian population are 600 mg each for Ca & P, 3225-3750 mg for K, 1900-2100 mg for Na, 310-340 mg for Mg, 1.7 mg for Cu (adequate intake), 17-21 mg for Fe, 40 μg for Se, 10-12 mg for Zn, and 4 mg for Mn. These essential minerals are rich in both wild-caught and farmed murrel fishes. Therefore, murrel fish can be considered a good source of essential minerals for consumers and a promising species for aquaculture diversification as well as an alternative for fish farmers for increasing profitability.

Table 1. Mineral profile of wild-caught and farmed murrel fishes

Elements (mg/Kg)	Wild-caught murrel		Farmed murrel	
	Muscle	Skin	Muscle	Skin
Ca	239.71±57.09[a]	3393.00±1.64[c]	289.93±127.62[a]	885.00±2.79[b]
K	2292.86±167.93[b]	2024.00±2.73[b]	2580.61±43.33[c]	880.10±2.79[a]
Na	225.70±6.01[b]	549.70±3.20[d]	190.18±6.37[a]	432.57±3.36[c]
P	2978.94±109.86a[b]	7069.00±1.56[d]	3246.58±169.18[c]	2662.93±2.11[a]
Mg	311.43±10.49[b]	404.90±4.69[c]	345.76±18.28[b]	171.57±5.38[a]
Cu	0.21±0.04[a]	0.35±18.27[b]	0.18±0.03[a]	1.42±1.58[c]
Fe	3.47±1.89[a]	15.89±5.58[b]	15.21±1.30[b]	18.84±4.65[c]
Se	0.84±0.08[a]	1.54±6.19[c]	1.19±0.05[b]	1.24±1.07[b]
Zn	1.67±1.03[a]	22.44±2.47[c]	6.39±0.45[b]	46.61±2.74[d]
Mn	0.52±0.06[a]	3.35±5.43[c]	0.86±0.29[a]	1.92±5.49[b]

Values are given as Mean±S.D. with different superscripts, indicating significant differences at $P \leq 0.05$

Figure 1a. Wild-caught murrel fish

Figure 1b. Biofloc farmed murrel fish

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Tetracycline enhanced the plaque size of lytic bacteriophages targeting Methicillin-resistant *Staphylococcus aureus* (MRSA) isolated from an aquatic environment

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Staphylococcus aureus including methicillin-resistant *Staphylococcus aureus* (MRSA) is a leading cause of both community- and hospital-acquired infections, including skin and soft tissue infections, wound infections, endocarditis, osteomyelitis, and life-threatening bacteremia (Kaur et al., 2012). It has been considered as a pathogen of “high priority” by the World Health Organization (Jesudason, 2024). To combat the development and spread of antimicrobial resistance (AMR), the use of alternatives to traditional antibiotics, such as **lytic bacteriophages**, is increasingly being recognized as a promising approach. In this regard, ICAR-CIFT has successfully isolated several lytic bacteriophages that are active against *S. aureus* including MRSA with broad host range activity. However, a major challenge in the isolation and purification of *S. aureus* phages is the frequent occurrence of minute, pinhead-sized plaques on media plates. These tiny plaques make it difficult to distinguish morphological differences, complicating the process of identifying and selecting phages for further clonal purification (Kaur et al., 2012; Santos et al., 2009). Previous studies have reported the use of β-lactam, quinolone, tetrazolium, kanamycin, and rifampicin to enhance phage plaque size, whereas, linezolid, tetracycline, ampicillin, and ketolides have been shown to increase plaque size in MRSA by up to three-fold (Kaur et al., 2012; Pattee et al., 1966; Santos et al., 2009). Various stages of the phage multiplication cycle have been reported to significantly influence plaque formation on solid media. Researchers have suggested using protein synthesis-inhibiting antibiotics to produce well-defined, larger plaques. In line with this approach, pinhead-sized and variably sized MRSA phage plaques were evaluated for their potential to form more distinct and larger plaques using a specific protocol. Tetracycline and linezolid were added at different concentrations to enhance plaque visibility without completely inhibiting bacterial growth. The findings revealed that tetracycline effectively increased plaque size and visibility, facilitating more accurate phage enumeration.

Phages were previously isolated from sewage samples using the multiple host enrichment method (George et al., 2022; Vaiyapuri et al., 2021). Three MRSA phages that produced very small, pinhead-sized, semi-transparent plaques were evaluated for plaque size enhancement by supplementing the media with tetracycline and linezolid before plating. The addition of tetracycline improved both plaque visibility and size (Fig. 1). Additionally, 18 phages that initially formed minute but countable plaques were tested, showing an increase in plaque size from <1 mm to 2–3 mm. The results indicated that tetracycline supplementation at a concentration of 0.25 μg/ml effectively enhanced plaque size. Whereas linezolid at 0.25 μg/ml and 0.125 μg/ml concentrations, and tetracycline at 0.125 μg/ml had no effect on plaque morphology. In conclusion, the work evaluated the improvement of plaque size and visibility of phages active against MRSA isolated from seafood markets and aquaculture settings, thus facilitating their isolation and purification.

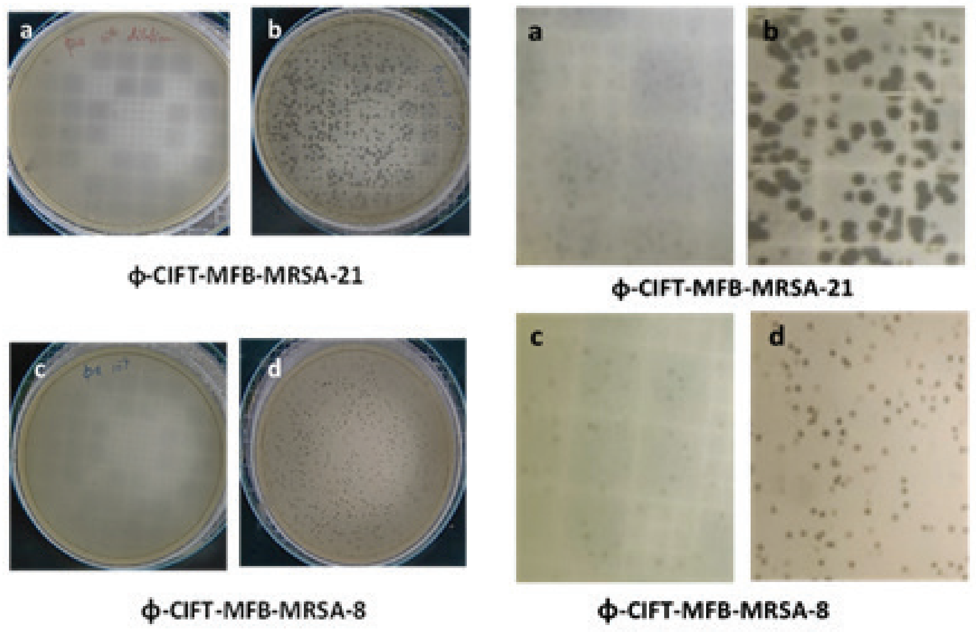

Figure 1. (a) φCIFT-MFB-MRSA-21 plaques without the addition of antibiotics (b) φCIFT-MFB-MRSA-21 plaques with the addition of tetracycline (c) φCIFT-MFB-MRSA-8 plaques without the addition of antibiotics (d) φCIFT-MFB-MRSA-8 plaques with the addition of antibiotics (the figure toward the right is an enlarged view of the same).

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Study on fish consumption and influencing factors in West Garo Hills (WGH) of Meghalaya, India

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The West Garo Hills (WGH) district of Meghalaya is located within the geographical coordinates of 25°20'N to 26°N lattitude and 89°40'E to 90°30'E longitude, with an average altitude of 657 m above mean sea level. The population of WGH consists 80% of tribals with the Garos being the predominant group followed by Hajong, Koch, Banai, and Rabha (Tarunkumar et al., 2016). A study was conducted to collect the socio-economic information of ethnic groups in WGH district of Meghalaya and also to estimate the per capita fish consumption (PCFC) and factors influencing the PCFC among the ethnic population.

The information on socio-economic characteristics collected from 134 surveyed individuals is given in Table 1. About 73% of the respondents belonged to the age group between 31 and 54 years and the rest are in other different groups. The average size of the family was 4-6 members with an average yearly income of ₹2,17,180.

Table 1. Socio-economic characteristics of individuals in WGH district of Meghalaya

Sl. No.	Variables		Frequency	Percentage	Mean
1.	Age	< 31 years	18	13.5	42.2
		31– 54	97	73	
		>42 years	18	13.5	
2.	Family members	<4	45	34	
		4-6	68	51	
		>6	20	15	
3.	Yearly income	<1,25,106	50	37.6	2,17,180
		1,25,016 – 3,09,254	50	37.6	
		>3,09,254	33	24.8	
4.	Monthly expenditure on fish	<600	43	21.5	1018.5
		600-1437	119	59.5	
		>1437	38	19	
5.	Spouse occupation	Employed	10	7.5	
		Housewife	123	92.5	

The study also investigated the fish purchasing and consumption habits of the respondents. It was found that approximately 42.1% of the individuals consume fish 2-3 times a week, while 43.6% consume fish at least once in a week. Additionally, 3.03%, consume fish 1-2 times in a week. On the other hand, a relatively lower percentage (8.27%) consume fish every two days, and only 2.25% consume fish on a daily basis. The fish purchase and consumption behaviour of the respondents is given in Figure 1.

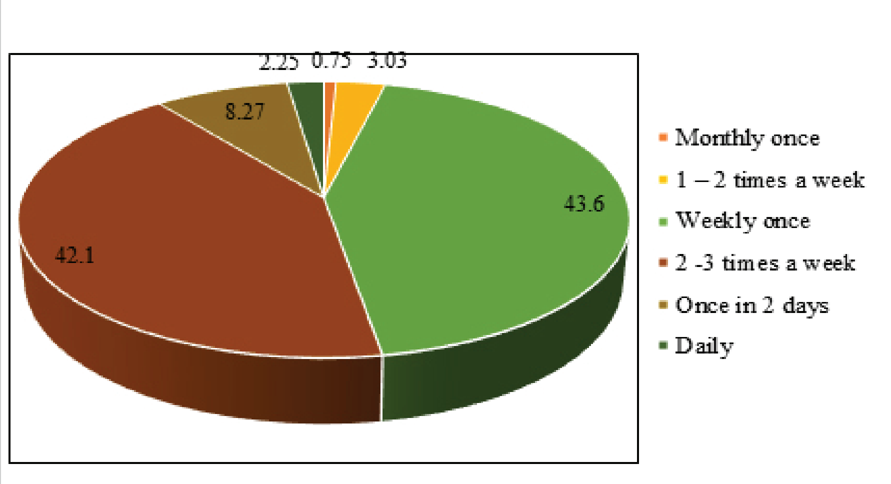

Figure 1. Fish purchase and consumption behaviour of the respondents in percentage

The estimated PCFC among the studied population was 12 kg/year, which was slightly higher than the state PCFC of 9 kg fish per year. It was observed that Rohu (46.6%) was the most frequently purchased fish, followed by Catla (25.6%) and common carp (18.8%) among the respondents. Other species *viz: Labeo bata*, Hilsa, Pomfret and Prawns were also purchased by the respondents. The study also determined the consumption pattern of dry fish among the respondents. It was observed that 86.5% of the respondents consume dry fish, whereas 9.8% of the respondents never consumed dry fish.

It was observed that among the variety of fish purchased, Rohu (25.6%) was the most favoured fish by the respondents, followed by Hilsa (21.8%), and Bata (15%). Other species included Catla (9.7%), Pomfret (7.5%), Common Carp (7.5%) and Catfish (3.85%). These results reflect the relative popularity or prevalence of each fish species with respect to their preference and consumption (Figure 2).

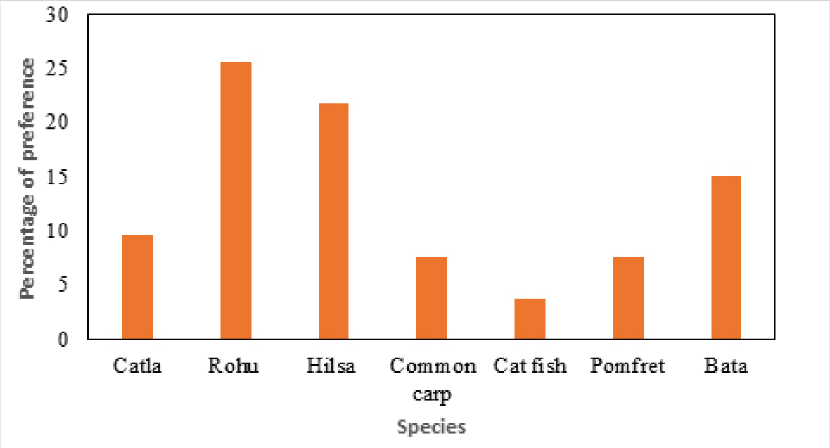

Figure 2. Preference of species of fish by the respondents for consumption

Table 2. Willingness to consume fish-based products

Sl No	Products	Yes		Undecided		No	
		n	%	n	%	n	%
1.	Fish soup	53	40.0	24	18.0	56	42.0
2.	Fish pappad	59	44.4	19	14.3	55	41.3
3.	Fish noodles	53	39.9	22	16.5	58	43.6
4.	Fish balls	60	45.1	18	13.5	55	41.4
5.	Fish cutlets	59	44.4	19	14.3	55	41.3
6.	Fish powder	52	39.1	24	18.0	57	42.9
	Average	56	42.0	21	15.8	56	41.0

The study also explored the preferences of the respondents when buying fish. It was observed that 54.1% of the participants considered their own preferences, while 16.5% took into account their spouse's preferences and 18.8% of the respondents preferred to consider their children's preferences, and 9% considered the preferences of their parents. The average quantity of fish purchased by the respondents during a single purchase was 0.95 kg. It was notably observed that a majority (66.9%) of the respondents indicated a uniformity in fish consumption among the family members while taking into account the variability in the family size as given in Table 1. Among the surveyed population, 82% of them prefer to have a combination of both fish curry and fried fish for the consumption. The majority (46%) of the respondents favoured to have fish during the lunch and 30% of the respondents prefer to have fish during dinner. A smaller percentage (2.2%) preferred to consume fish as a morning meal.

The study also examined the willingness of the respondents to consume various fish-based products. The results are being presented in the Table 2. It was observed that 42% of the total respondents were willing to have fish-based products, whereas rest of the respondents either were not willing or undecided to consume fish-based products.

It could be inferred from the results that **nearly 50%** of the respondents expressed their willingness to consume fish-based products, which will definitely improve the nutritional status of that group as they recognize the nutritional benefits of fish and related products. A high percentage of respondents expressed their non-willingness to consume fish-based products. This might be due to their personal preferences, dietary restrictions, or other reasons influencing their decision to abstain from such products. Nearly 15.8% remained undecided about the willingness to consume fish-based products due to lack of information on the potential benefits of fish-based products in improving the nutritional status. This lack of information or knowledge can be improved through education, training and awareness programmes about the positive effect of fish consumption on nutritional health. The positive as well as negative responses can be taken as an opportunity to impart training and awareness programmes to improve the benefits of fish and fish-based products consumption, which in turn increases the total fish consumption.

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Navigating challenges in online fish retailing: Insights from Ernakulam, Kerala

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The online fish retailing sector in Ernakulam, Kerala, has seen substantial growth in recent years (Sajeev, 2021). This growth is driven by the increasing demand for fresh fish delivered to the doorstep, a trend accelerated by the Covid-19 pandemic (Sajeev et al., 2021). However, this burgeoning sector faces numerous challenges, including supply chain disruptions, seasonal availability issues, and competition (Sajeev & Joshy, 2023). This study delves into these issues and explores the coping strategies employed by various online fish vendors in the region. The insights are drawn from interviews with five major and minor players in the market, offering a comprehensive view of the industry's landscape.

The study involved structured interviews with representatives from five online fish vending firms in Ernakulam,three major players and two firms that faced significant operational challenges leading to their closure. The vendors were operating from Kadavanthra, Chambakkara, Edapally, Puthuvype and Kannamaly in Ernakulam district, Kerala. A set of 32 questions were used to gather detailed information about their operations, challenges, and strategies employed.

One of the primary issues faced by online fish vendors in Ernakulam is the seasonal fluctuations in availability of fish. Vendors reported maximum availability of fish after the trawl ban period, particularly in August and September. Conversely, the least availability occurs during December and the trawl ban months of June and July. These seasonal fluctuations significantly impact inventory levels and pricing strategies. Procurement is another significant challenge, with vendors sourcing fish from multiple locations such as Munambam, Kalamukku, Thoppumpady, Aroor, Varapuzha, and Chambakkara in Ernakulam District. Competition at fishing harbours, especially during auctions, exacerbates the procurement issues. Moreover, unexpected weather conditions and trawling regulations further hinder the consistent supply of fresh fish. To mitigate these challenges, vendors have developed robust strategies. Procuring fish from small boats and local fishermen during periods of low availability ensures a continuous supply. This approach is particularly effective during weather warnings and seasonal bans, allowing vendors to maintain stock levels and meet customer demands.

Price volatility is a persistent issue in the fish retail industry (Sajeev et al., 2023). Vendors noted that online prices are at their lowest from February to May and peak in December. Several factors influence fish prices, including the buying price, availability, and seasonal demand. For instance, the price of Seer fish can range from ₹500-600 per kg during low-demand periods to ₹1500 per kg in December. To manage price volatility, vendors typically add a markup of 10-20% to the actual purchase price. This markup helps cover operational costs and ensures profitability despite fluctuations in the market. Additionally, vendors closely monitor market trends and adjust prices accordingly to stay competitive.

Digital marketing plays a crucial role in the success of online fish retailing. The surveyed vendors utilize a variety of marketing channels, including newspapers, radio, TV ads, billboards, YouTube, WhatsApp, Facebook, and Instagram. These platforms help in reaching a broader audience and attracting potential customers. However, challenges persist in digital marketing. Some vendors highlighted a lack of awareness about online marketing strategies and limited resources for proper advertisement. Additionally, technical issues related to online transactions can deter customers from making purchases. To address these issues, vendors focus on enhancing their digital presence through targeted marketing campaigns and improving the user experience on their online platforms. Providing clear information about product quality, hygiene, and unique selling points (USPs) such as visible cutting patterns and product replacement guarantees can build customer trust and encourage online purchases.

Operational challenges such as managing a consistent workforce and dealing with government regulations also impact the online fish retail business. Vendors reported difficulties in maintaining a sufficient number of employees, especially for online sales. Government regulations related to packaging, GST, and labelling requirements add to the operational burden. To cope with workforce challenges, vendors employ part-time workers during peak hours and streamline their operations to ensure efficiency. Regulatory compliance is managed by adhering to government guidelines and investing in appropriate packaging solutions that meet the required standards.

Table 1. Issues and coping strategies followed by vendors and suggestions for improvement of online marketing

Sl. No.	Issues	Coping strategies followed	Suggestions for improvement
1	Seasonal fluctuations in availability	Procuring fish from small boats and local fishermen during low availability periods	Develop partnerships with more diverse suppliers to ensure a continuous supply
2	Price volatility	Adding a markup of 10-20% to the actual purchase price	Implement dynamic pricing strategies using real-time market data
3	Supply chain disruptions	Sourcing fish from multiple locations such as anonymized fishing hubs	Invest in better logistics and supply chain management systems to enhance resilience
4	Digital marketing challenges	Utilizing multiple marketing channels: newspapers, radio, TV ads, billboards, YouTube, WhatsApp, Facebook, Instagram	Provide training on digital marketing strategies and allocate more resources for targeted online advertisements
5	Operational challenges	Employing part-time workers during peak hours and streamlining operations	Implement workforce management software to optimize employee scheduling and productivity
6	Regulatory compliance	Adhering to government guidelines and investing in appropriate packaging solutions	Establish a dedicated compliance team to stay updated with regulations and ensure timely adherence
7	Customer engagement	Enhancing digital presence through targeted marketing campaigns and improving user experience	Introduce loyalty programs and personalized marketing to increase customer retention
8	Technical issues in online sales	Addressing technical issues to prevent deterring customers from making purchases	Invest in robust e-commerce platforms and IT support to minimize technical glitches
9	Procurement issues	Maintaining a diverse inventory to cater to varying customer demands	Foster long-term relationships with suppliers and explore bulk purchasing options to stabilize procurement costs
10	Competition at fishing harbours	Competing effectively during auctions to secure quality fish	Collaborate with other vendors to negotiate better prices and reduce competition at sourcing locations

Table 1 encapsulates the primary challenges faced by online fish retailers in Ernakulam, the strategies they employ to mitigate these challenges, and potential areas for further improvement to enhance their operations and market position.

The COVID-19 pandemic and related restrictions, such as lock downs, containment zones, and curfews, have posed significant disruptions to the fish retail industry. Despite these challenges, online fish vendors in Ernakulam have demonstrated resilience through various coping strategies. During the pandemic, vendors shifted their focus to online sales and home deliveries, ensuring that customers continued to receive fresh fish without the need to visit physical stores. This approach not only maintained sales but also catered to the growing demand for contactless shopping options. In response to restrictions on fish trade and fishing trips due to weather warnings, vendors procured fish from small boats and local fishermen, ensuring a steady supply. This adaptability in sourcing helped mitigate the impact of external disruptions on their business operations.

The study also included insights from two firms that faced operational difficulties and eventually closed down. While the first one faced challenge in maintaining a steady supply due to climatic changes and high competition in fishing harbours, the other firm cited procurement issues and competition as major challenges. Similarly, the reliance on a limited number of sources and the high cost of maintaining compliance with government regulations contributed to its closure. Despite having a streamlined online selling process and a diverse inventory, the first firm struggled with procurement issues and fluctuating fish prices. However, the second firm had successfully implemented advanced packaging technologies, which other vendors can learn from.

The online fish retailing sector in Ernakulam, Kerala, faces several challenges, including seasonal availability, price volatility, supply chain disruptions, digital marketing hurdles, operational and regulatory compliance issues, and competition at fishing harbors. Vendors cope with these challenges by sourcing from small boats and local fishermen, employing dynamic pricing, utilizing diverse marketing channels, optimizing workforce management, and adhering to government regulations. They also shift focus to online sales and home deliveries during disruptions, enhance digital presence, and invest in robust IT support to address technical issues. Learning from failed ventures, particularly in procurement and packaging technologies, vendors continuously adapt to ensure a consistent supply of quality fish. Further improvements could involve developing diverse supplier partnerships, implementing advanced logistics and workforce management systems, providing digital marketing training, and fostering long-term supplier relationships to stabilize procurement costs.

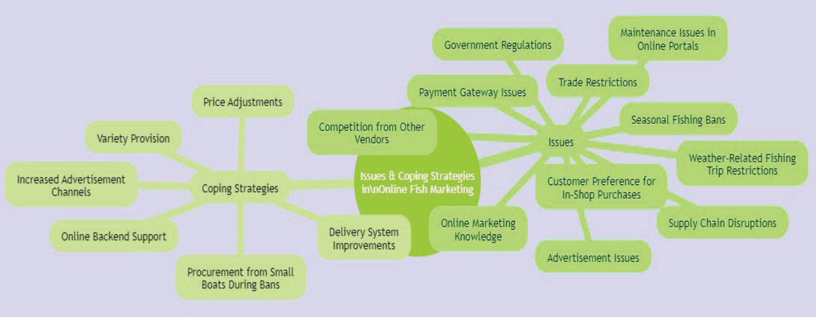

Figure 1. Mind-map on issues and coping strategies in online fish retailing in Ernakulam, Kerala

The digital shift in fish marketing not only enhances accessibility but also supports local fisheries and promotes sustainability. The online fish retailing sector in Ernakulam, Kerala, faces a myriad of challenges, from seasonal availability and price volatility to digital marketing and operational hurdles. However, the innovative coping strategies employed by vendors demonstrate their resilience and commitment to maintaining a consistent supply of quality products to their customers (Figure 1). By leveraging local resources, enhancing digital marketing efforts, and adhering to regulatory requirements, these vendors continue to thrive in a competitive and dynamic market.

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