# FISHTECH REPORTER

VOL.09 (1) JANUARY - JUNE 2023

भा कृ अनु प - केंद्रीय मात्स्यिकी प्राद्योगिकी संस्थान
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**FishTech Reporter**
Vol 09(1) January - June 2023



Published by: The Director, ICAR-CIFT

From the Editorial Board

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Fish processing technology is a rapidly evolving field that has significant implications for the food industry, the environment, and human health. In this editorial, I will highlight some of the recent advances and challenges in this area, and provide an overview of the 15 articles that are featured in this issue of the FishTech Reporter.

Capture fisheries provide food, income, and livelihoods for millions of people around the world, as well as contribute to the conservation and management of aquatic ecosystems. Capture fisheries also face many challenges, such as overfishing, pollution, climate change, and illegal fishing, that threaten their sustainability and productivity.

One of the main goals of fish processing technology is to improve the quality, safety, and shelf-life of fish products while reducing waste and environmental impact. Another important aspect 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 peptides. These products have potential uses in food, pharmaceutical, cosmetic and biomedical industries, as they possess various biological activities such as antioxidant, anti-inflammatory, antimicrobial, antihypertensive and wound healing.

In this issue, two important articles detail the incidence of juveniles in beach seine operations and biodegradable fishing nets. In the processing side, there are articles on dried shrimp, drying interventions, quality aspects as well as colour estimation protocol and biochar from seaweed as water purification which may be of interest to the readers. There are also articles in the social sciences indicating the women labour in fisheries, fish consumption pattern, online fish marketing and fish meal export and imports.

However, fish processing technology also faces some challenges and limitations that need to be addressed. These include regulatory issues, consumer acceptance, cost-effectiveness, scalability and sustainability. Moreover, there is a need for more research on the safety and efficacy of novel fish products and ingredients, as well as their interactions with other food components and human physiology.

In conclusion, 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.

# Index

# Biodegradable Fishing Nets: A Sustainable Solution for the Oceans

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## INTRODUCTION

Plastic pollution in the world's oceans has reached alarming levels, with fishing gear being a significant contributor to this environmental crisis. To combat this issue, the development and use of biodegradable fishing nets have emerged as a promising solution. This article explores the concept of biodegradable fishing nets, their benefits, challenges, and the potential they hold for a more sustainable fishing industry and healthier marine ecosystems.

Biodegradable fishing nets are designed to break down naturally in the marine environment over time, reducing the long-lasting environmental impact associated with traditional synthetic fishing nets. These nets are made from materials that can be decomposed by natural processes, such as microorganisms, sunlight, and water, into harmless components that assimilate back into the ecosystem. Kim et al., (2016) explore biodegradable polymers as a possible solution to the issue, for passive fishing gear such as gillnets and trammel nets. These nets had only slightly lower catch rates than conventional nylon nets in field tests, and yet they showed clear signs of degradation within 2 years of introduction to salt water. Globally, 6.4 million tons of fishing gear are lost in the oceans annually. This gear (i.e., ghost nets), whether accidentally lost, abandoned, or deliberately discarded, threatens marine wildlife as it drifts with prevailing currents and continues to entangle marine organisms indiscriminately (Wilcox et al., 2015). Cha et al., (2011), developed biodegradable fishing pots made up of biodegradable (Polybutylene Succinate and Polybutylene adipate-co-terephthalate) to reduce plastic pollution problem in the sea and carried out experimental fishing in comparison with Polyethylene (PE) octopus pots. The result is very similar to the comparison of total catches by each type of the pot. In terms of bycatch, the number of species, amount of catches and the number of fishing with bycatch were more significant in the biodegradable pots than in the PE pots.

### Benefits of Biodegradable Fishing Nets

- Environmental Sustainability: Biodegradable fishing nets offer a significant advantage over traditional nets as they minimize the accumulation of plastic waste in the oceans. By breaking down into natural components, they reduce the risk of entanglement for marine life and the persistence of ghost nets that continue to capture and harm marine organisms.

- Reduced Plastic Pollution: Fishing gear, including nets, is a major source of plastic pollution. By utilizing biodegradable materials, fishing nets can contribute to reducing the amount of plastic debris in the oceans, mitigating the adverse effects on marine ecosystems and the food chain.
- Improved Marine Conservation: Biodegradable nets help protect marine biodiversity by reducing the unintended capture and entanglement of marine organisms. This preservation of marine life contributes to the overall health and resilience of marine ecosystems, promoting sustainable fishing practices and ensuring the long-term viability of fish stocks.

## Methods for Developing Biodegradable Fishing Nets

The development of biodegradable fishing nets requires careful consideration of materials, manufacturing processes, and performance requirements. Here are several methods and approaches that can be used to develop biodegradable fishing nets:

**Material Selection:** Choosing the right materials is crucial in developing biodegradable fishing nets. Consider the following options:

a. Natural fibres: Utilize natural fibres such as jute, hemp, or sisal as the primary material for net construction. These fibres are renewable, biodegradable, and have potential for good strength and durability.

b. Biodegradable Polymers: Explore the use of biodegradable polymers derived from renewable sources, such as polylactic acid (PLA), polyhydroxyalkanoates (PHA), or polybutylene adipate terephthalate (PBAT). These polymers break down into harmless components in the marine environment.

c. Composite Materials: Combine biodegradable polymers or natural fibers with durable structural elements to create composite materials. This approach can enhance the strength and durability of biodegradable fishing nets while still maintaining biodegradability (Fig 1).

*Fig 1. Hardened biodegradable fishing nets using nano-technology*

**Manufacturing Processes:** Developing suitable manufacturing processes is essential to ensure the production of high-quality biodegradable fishing nets. Consider the following approaches:

a. Net Weaving: Use traditional net weaving techniques but replace synthetic fibers with biodegradable materials. Adapt existing manufacturing equipment to handle the specific properties of biodegradable fibers or polymers.

b. Additive Manufacturing: Explore additive manufacturing techniques, such as 3D printing, to create biodegradable fishing nets with complex designs and customized properties. This method allows for precise control over net structure and material distribution.

c. Coating and Treatment: Apply biodegradable coatings or treatments to enhance the biodegradability of existing fishing nets. These coatings can be designed to break down over time, allowing the underlying net material to degrade naturally.

**Performance Testing and Optimization:** Biodegradable fishing nets must meet performance requirements to ensure their effectiveness in fishing operations. Conduct thorough testing and optimization processes, including:

a. Strength and Durability Testing: Evaluate the tensile strength, abrasion resistance, and overall durability of biodegradable net materials through laboratory and field testing. Optimize material composition and manufacturing processes to meet the required performance standards.

b. Environmental Compatibility Testing: Assess the behavior of biodegradable fishing nets in different marine environments to ensure they break down efficiently without causing harm to marine life or ecosystems. Consider factors such as temperature, salinity, and microbial activity.

c. Comparison to Conventional Nets: Compare the performance of biodegradable fishing nets to conventional synthetic nets to ensure they meet or exceed industry standards in terms of strength, handling, and fish-catching efficiency.

Nano particles can be incorporated into biodegradable fishing nets to enhance their properties and performance. Here are some possible nano particles that can be used in the development of biodegradable fishing nets:

1. Nano Cellulose: Nano cellulose particles, derived from cellulose fibers, offer excellent mechanical properties and can reinforce biodegradable materials. They can enhance the strength, durability, and tear resistance of fishing nets while maintaining biodegradability.
2. Nano Chitosan: Chitosan is a biodegradable polymer derived from chitin; a natural substance found in the shells of crustaceans. Nano-sized chitosan particles can be incorporated into fishing nets to improve their mechanical strength, flexibility, and resistance to microbial degradation.
3. Nano Clay: Nano clay particles, such as montmorillonite, can be used as fillers in biodegradable polymers to enhance their mechanical properties. These particles improve the tensile strength, impact resistance, and thermal stability of the fishing nets.
4. Nano Calcium Carbonate: Nano-sized calcium carbonate particles can improve the mechanical properties of

biodegradable materials used in fishing nets. They can enhance tensile strength, flexibility, and resistance to impact and abrasion (Boyjoo et al., 2014).

5. Nano Titanium Dioxide: Nano titanium dioxide particles possess antimicrobial and UV-blocking properties. Incorporating them into biodegradable fishing nets can help reduce microbial growth and protect the nets from UV degradation, extending their lifespan (Yeung et al., 2009).

6. Nano Silver: Nano silver particles exhibit antimicrobial properties and can inhibit the growth of bacteria, fungi, and other microorganisms. Adding nano silver to biodegradable fishing nets can help reduce biofouling, preventing the accumulation of unwanted organisms on the nets (Fig 2).

7. Nano Zinc Oxide: Nano zinc oxide particles have antimicrobial and UV-blocking properties. Their incorporation into biodegradable fishing nets can provide protection against microbial growth and UV degradation, ensuring the longevity of the nets.

*Fig 2. Biodegradable fishing nets with nano particles*

It is important to note that the use of nano particles in biodegradable fishing nets requires careful consideration of their environmental impact. Studies on the potential release and behaviour of these particles in the marine environment should be conducted to ensure they do not pose unintended harm to marine life or ecosystems.

The selection of nano particles depends on specific requirements and desired properties of the fishing nets. Researchers and manufacturers should conduct comprehensive studies to evaluate the effectiveness, safety, and environmental compatibility of these nano particles before their widespread implementation in biodegradable fishing nets.

## Challenges and Considerations

While biodegradable fishing nets offer numerous benefits, there are challenges to address to ensure their widespread adoption and effectiveness:

1. Durability and Performance: Bio-degradable materials may not possess the same durability and strength as traditional synthetic materials like nylon. Therefore, it is essential to develop biodegradable fishing nets that can withstand the rigorous conditions of fishing operations without compromising performance and safety.

2. Cost and Availability: Currently, bio-degradable fishing nets can be more expensive than conventional nets due to the higher costs associated with the production of biodegradable materials. However, as technology advances and

demand increases, economies of scale can lead to cost reductions, making biodegradable options more accessible to fishermen.

3. Proper Disposal and End-of-Life Management: To ensure the effectiveness of biodegradable fishing nets, it is crucial to educate fishermen about their proper disposal and end-of-life management. Nets should be collected, treated, and disposed of in a way that allows them to break down naturally without causing harm to the environment.

4. Research and Development: Continued research and development efforts are essential to improve the performance, durability, and affordability of biodegradable fishing nets. Collaboration between scientists, engineers, and fishing industry stakeholders can drive innovation and accelerate the development of more sustainable alternatives.

## Conclusion

The development and adoption of biodegradable fishing nets offer a promising solution to address the environmental challenges associated with plastic pollution in the fishing industry. By minimizing plastic waste, reducing the impacts on marine life, and promoting sustainable fishing practices, biodegradable nets can contribute to healthier oceans and a more sustainable future. It is crucial to continue investing in research, development, and education to overcome challenges, enhance the effectiveness of biodegradable fishing nets, and create a positive impact on marine ecosystems worldwide.

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# *Report on High Juvenile Incidence in Beach Seine Operations off Kovalam, Kerala*

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Beach seines are fishing gears operated from the shore for encircling a school of fish in shallow coastal waters. The design and size of beach seines vary based on geographical factors and the target fishery. A typical beach seine in Kerala are locally known as *kambavala* or *karamadi* with two long hauling warps/Kamba, wings/kayaru, and a funnel net (Lekshmi et al., 2019). During fishing operations, one group of fishers remains onshore, holding one end of the hauling rope, while the second group takes the gear on a boat along with the other end of the rope. When a fish shoal is spotted, the second group encircles the shoal at a distance from the starting point and returns to the shore. The hauling ropes are then simultaneously pulled from the shore by the two groups of fishers, gradually closing the distance between them as the codend approaches the shore. The fishing operation typically lasts from 1 to 5 hr.

*Beach seine operation at Kovalam beach, Thiruvananthapuram*

Kovalam beach in Trivandrum, Kerala along the southwest coast of India, is one place where beach seine finds as an important fishing activity and plays a significant role in the local economy, and supports the livelihoods of coastal communities. Beach seines are mainly targeted for the coastal pelagic shoals. The dominant species landed by Karamadi from Trivandrum includes mackerel, sardines, lesser sardines, anchovies, silver bellies, halfbeaks, full beaks, trevallies, herrings, silver whitings, lizardfish, shrimp, etc. (Edwin et al., 2020). Normally beach seines are non-selective fishing gears with small mesh sizes and are operated mainly during the post-monsoon season due to the high availability of coastal pelagic fishes. However, there is a growing concern over the high incidence of juvenile fish caught in beach seines, due to small codend mesh sizes below 10 mm which can have detrimental effects on fish stocks and the overall sustainability of the ecosystem. In certain months especially during the monsoon and post-monsoon, more than 80% of the catch were juveniles of coastal pelagics. Surya et al. (2015) reported from the Dhanuskodi Island, Tamil Nadu where more than 75% of the catch were juveniles. Saleela et al. (2015) suggested to increase the codend mesh size of beach seines from 6mm to 25 mm.

*Codend mesh used in beach seine of Kovalam*

*Juvenile fish landed in the beach seine fishery of Kovalam*

*Sorting of Juvenile fishes for auction*

*Sale of Juvenile fish in the local market*

The study highlights the implications of juvenile fishing during beach seine operation in Kerala. ICAR-CIFT formulated guidelines for the operation of beach seines along the Kerala coast to reduce the incidence of juveniles, the existing cod-end mesh size of below 10 mm has to be increased to 22mm. As per the guidelines, square mesh is recommended at the cod-end region to facilitate the escape of juvenile fishes (Edwin et al., 2022).

Beach seining is an age-old traditional declining fishing method and currently this gear is considered only as a secondary option for livelihood of the fisher of Kovalam, Kerala. The present study points the facts that even though there is a reduction in the number of beach seines in Kerala, the dimensions of the gear increased during the last decades as in the case of other pelagic gears. Technical and operational improvements of the gear and policies for the reduction of juvenile catches in seines need to be developed which would support the sustainability of beach seine fisheries in Kerala.

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# *Pre-processing protocol for the drying of peeled and undeveined (PUD) Penaeus vannamei*

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Dried shrimp is one of the most delicious seafood in many parts of the world. In India, the drying of shrimp is a major entrepreneurship in the coastal states. Apart from the direct use, dried shrimp is used as raw material for the production of shrimp snacks such as wafers, crackers, chips, etc. So, the demand and production of dried shrimp are always expected to increase over the years. Most commonly, small-sized shrimps are dried as shell-on. Color is the most important quality criterion deciding the consumer acceptability of dried shrimp, but the color of shell-on dried shrimp is not always appealing as melanosis development in the shell imparts a blackish tinge to the dried shrimp.

Andhra Pradesh is the leading producer of Pacific white shrimp Penaeus vannamei in India. Though drying of *P. vannamei* is an uncommon practice in India, it can be used as a cost-effective method to preserve the catch after unexpected harvesting during disease outbreaks on the farm. Pickle made from dried shrimp is a delicacy in some districts of Andhra Pradesh. Shell-less dried shrimp is used as the raw material for making dried shrimp pickles. For making pickles out of dried shrimp, comparatively bigger-sized shrimps are chosen. In this communication, a pre-process protocol for drying *P. vannamei* is discussed.

*Penaeus vannamei* of average size 10 g was selected. One batch of shrimp was beheaded, peeled, and divided into three lots and blanched in 3% brine containing 0.1% citric acid for 30 sec (A1) 60 sec (A2), and 90 sec (A3). The peeled and blanched shrimps (A1, A2 and A3) were dried at 55-60°C for 8 h in a hot air oven. Another batch of fresh shrimp was beheaded and blanched for 30 sec, 60 sec, and 90 sec, coded as B1, B2, and B3, respectively. This batch of shrimps (B1, B2, and B3) were peeled after blanching and dried as earlier. One batch of peeled shrimp (C1) and shell on control (C2) was dried without the blanching process. Blanching loss, drying yield, rehydration rate, and color attributes of the dried shrimps were compared.

The blanching loss of the shrimps that were blanched after peeling (A1-A3) was markedly higher than those peeled after blanching (B1-B3) (Fig1). Consequently, the yield after drying was higher for the shrimps that were peeled after blanching. As expected, the increase in time of blanching increased the blanching loss markedly, but the effect of blanching time on the yield of dried shrimp was negligible.

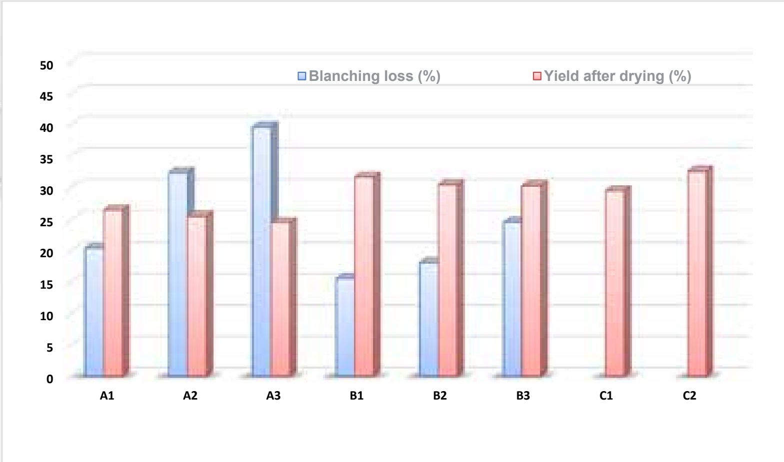


*Fig 1. Blanching loss and yield of dried P. vannamei*

Rehydration property is an important criterion for dried food products. It represents the water-absorbing efficiency of the dried food while soaking in water. Different blanching processes influenced the rehydration rate of dried shrimp (Fig 2). Peeled and blanched shrimps (A1-A3) showed a higher rehydration rate compared to blanched and peeled shrimps (B1-B3). This can be explained by the reason that during the blanching of peeled shrimp, more moisture and soluble materials were lost, giving rise to more capillaries, which might have facilitated the absorption of water into the muscle. Many studies suggest that cellular and structural arrangements in the food matrix influence the flow of water during rehydration (Gautam et al., 2021). It is also important to note that rate of rehydration increased as the time of the blanching period increased. The control sample dried with a shell had the highest rehydration rate among all dried shrimp samples because more water is entrapped in the space between the shell and meat.

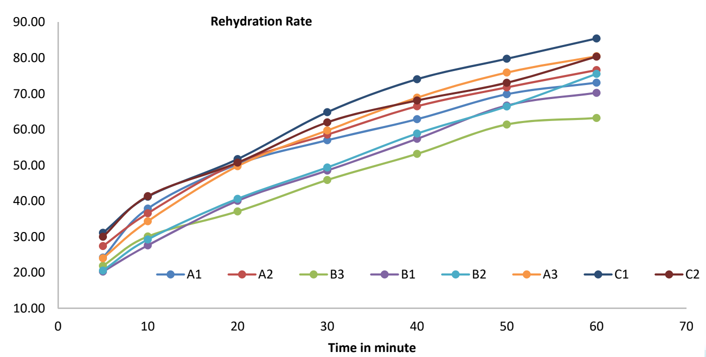


*Fig 2. Rehydration rate of dried P. vannamei*

The important finding of the study was the effect of blanching processes on the color attributes of dried shrimp. Visual examination clearly pointed out a marked difference in the redness of dried shrimp processed by different methods (Plate 1). This finding was supported by the instrumental color attributes as the *a** value (greenness to redness) was significantly higher in blanched and peeled shrimps than in peeled and blanched shrimp (Table 1). Astaxanthin is the carotenoid pigment found in shrimp that changes to a reddish tinge after drying. In peeled and blanched shrimp (A1-A3), a major loss of carotenoids on the surface of shrimp might have occurred whereas in samples B1-B3, since peeling was done after blanching, the epithelial layer between shell and meat that possesses more astaxanthin pigment retained intact and preserved the pigments. The lightness value *(L*)* and yellowness value *(b*)* were more in samples A1-A3 compared to samples B1-B3. Another observation was that the curling of shrimp meat during the blanching process was reduced when blanching the shell on the shrimp.

*Table 1. Hunter values (n=5) of peeled and dried P. vannamei*

| Sample | L* | a* | b* |
|---|---|---|---|
| A1 | 48.88 ± 0.56 | 21.39 ± 0.74 | 28.87 ±0.87 |
| A2 | 45.19 ±1.55 | 21.47 ± 1.28 | 27.98 ±0.84 |
| A3 | 45.71 ±1.51 | 23.01 ±0.30 | 28.24 ±0.65 |
| B1 | 39.04 ±1.05 | 24.04 ±0.77 | 25.78 ±0.97 |
| B2 | 38.39 ±1.53 | 24.67 ±0.99 | 25.80 ±0.89 |
| B3 | 41.40 ±1.19 | 24.40 ±0.61 | 26.35 ±0.30 |
| C1 | 35.13 ± 0.50 | 18.98 ±0.77 | 24.45 ±0.34 |
| C2 | 41.91 ±0.92 | 13.16±1.13 | 19.39 ±0.95 |

In conclusion, the study illustrates that peeling of shrimp after blanching process is more advantageous in reducing the blanching loss and improving the redness value and yield of dried shrimp. Moreover, 30 sec blanching time was found reducing the blanching loss. These findings from the study are useful for the seafood entrepreneurs in deciding the best process protocol for drying peeled shrimps.

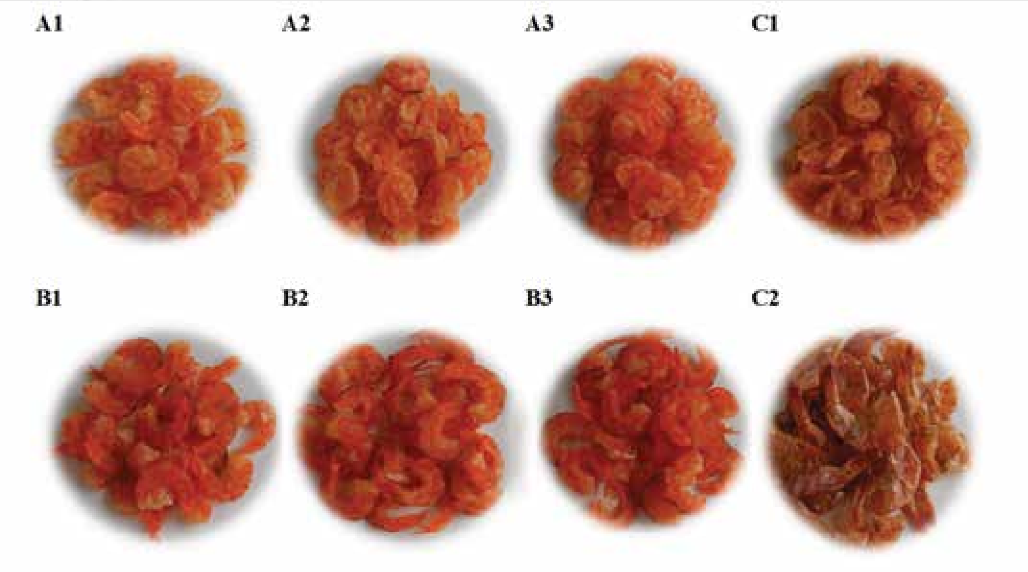


*Plate 1. Peeled and dried Penaeus vannamei*

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# *Quality Characteristics of Microwave and Sundried Chitosan: A comparative study*

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Chitosan is derived from chitin, which is one of the supreme abundant polysaccharides found in nature subsequent to cellulose. Generally, chitin is prepared from the exoskeleton of shrimp, crab, crayfish, and krill etc. Chitosan is chemically called a β (1,4) linked copolymer of D-glucosamine and N-acetyl-D-glucosamine. Chitosan has wide applications including food, pharmaceutical, textiles and effluent treatment etc. In general, the processing of chitin to chitosan from crustacean shells involves deproteinization, demineralization and deacetylation. Then it is dried under the sun and packed. The drying of chitosan under the sun is a time-consuming process. Hence, an improved drying process for chitosan is needed for the Industry to speed up the drying process without affecting its properties. The Present study is aimed to reduce the drying time of chitosan by microwave drying and to study its quality characteristics. The chitin prepared from shrimp shells was procured from the chitin Industry and it was subjected to 40% NaOH treatment under a cold process. Then it was subjected to microwave drying (Fig.1). The microwave power was used in the range from 400watts to 1600watts. The quality parameters of chitosan include moisture, ash (AOAC, 2019), degree of deacetylation (DD) (Kim, 2010), viscosity (Brookfield viscometer), water and fat binding capacity (Wang and Kinsella, 1976) and color (Hunter color analyzer) were analyzed and it was compared with the chitosan dried under the sun.

The moisture of chitosan was 3.35% for the sundried one. The chitosan dried in a microwave, had a moisture content between 5.53 %- 7.58%. The Ash content of chitosan varied from 0.50% to 1.43%. The Lowest drying time (23min) was achieved for chitosan processed under 1600watts than sundried one (120min). The DD of chitosan was between 77.3% - 80.8%. The viscosity of chitosan was found to be higher (2117Cp) for chitosan dried at 1000watts than sun-dried one (828.50Cp) (Table 1). The highest L* value (74.70) was found in sun-dried chitosan than microwave-dried (*L** : 71.22-72.73) chitosan. The highest WBC was observed for 1400w processed chitosan. Moreover, chitosan dried at 400watts showed a higher fat binding capacity (Table 1). There is no significant change in the thermal behavior and structural pattern of chitosan subjected to various drying conditions as indicated by DSC and FTIR analysis. Results suggested that the microwave drying process could reduce the drying time without affecting the structural pattern of chitosan.


Fig. 1. Microwave drying of chitosan

Table 1. Properties of microwave and sun-dried chitosan

| Sample | Drying time (min) | Moisture (%) | Viscosity (Cp) | WBC (g of water/ g chitosan) | FBC (g of oil/g chitosan) |
|---|---|---|---|---|---|
| Sun-dried | 120 | 3.35 | 828.50 | 4.47 | 10.29 |
| 400w | 70 | 6.77 | 1868.50 | 4.58 | 13.75 |
| 600w | 43 | 5.53 | 2086.33 | 3.09 | 11.20 |
| 800w | 40 | 6.83 | 1919.00 | 2.69 | 10.52 |
| 1000w | 35 | 6.17 | 2117.00 | 3.80 | 10.51 |
| 1200w | 33 | 6.85 | 1851.16 | 4.01 | 10.17 |
| 1400w | 33 | 6.57 | 1977.83 | 4.99 | 11.81 |
| 1600 w | 23 | 7.58 | 1483.33 | 4.65 | 12.30 |

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# *Ready to cook marinated blood clam*

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Blood clam (Anadara granosa), locally known as Khube in Marathi is a local delicacy among the fish-eating population in Maharashtra. In Indonesia, this product is considered as economically valuable fishery. As per the reports, this species is known for its survival at low oxygen levels hence they can remain alive in the absence of water (Hameed et al., 2015 & Gabriel et al., 2011). This species is known for its red body pigment (Hemoglobin) from which it derived its name blood clam (Bao et al., 2013). Hemoglobin (Hb) is the protein which contains iron that aids in carrying oxygen inside the body. It act as a transporting agent to carry oxygen from lungs to a different part of the body and elicits back carbon dioxide from cells to lungs for removal from the body. Iron also plays a major role in providing immunity. The concentration of Fe and Zn is high in blood clam which are essential constituents of human body and can be assimilated as it is available in easily absorbable form when compared to that of plant source (due to the absence of phytate).

On the other hand, Iron (Fe) and zinc (Zn) are essential elements required by the body, representing as constituents of enzymes and further essential proteins for carrying out metabolism

Blood calm inhabits on the open sandy region of the intertidal zone, submerged and immerse themselves just below the ground surface for getting nourished in shallow water from retiring tide. A huge quantity of seawater is filtered from where it gets the food. In Indonesia, cockles are preferred to be consumed as a whole. These bivalves are the source of volatile compounds which are the key determining source for its flavor (Shahidi 1998). In Italy, clam sauce is a delicacy for the fish-eating community. Blood clam is known as a promising food source of nutrients having better economic value with protein (9-13%), fat (0-2%), glycogen (1-7%), omega-3, vitamin A, vitamin B12 and vitamin C (Triatmaja et al 2019). This bivalve is known for minerals, especially Zn, Fe, Se and Cu. In some instants, this particular species is employed as bioindicator for seawater pollution as they are filter feeders and bio accumulators (Halit et al 2017), and act as a stockpile for heavy metals in contaminated water bodies.

Due to the increasing demand among consumers, this particular species are harvested intensively around the Vashi region of Maharashtra. These bivalve species are now available in online fish-selling portals under steamed and shucked form and sold at a better price. It was reported that the cooked cockle meat has good meaty texture, appealing sweetish taste, better flavour and reddish-brown colour. To popularize cockle meat among the local population it was required to develop some tempting products from cockle meat.

As Ready to Cook food products are gaining consumer preference, a Ready to Cook marinated Clam product was developed. Live blood clam was procured, bought to the laboratory and kept in clean seawater for 16-24 h to empty the gut (Nowak, 1970). The shells were thoroughly washed thrice with potable water. The calm was steamed and the meat was shucked. The collected meat was made into 3 lots viz., Control Group, Malvani group (marinated with Malvani masala) and Kholapuri group (marinated with Kholapuri masala). The two marinated ready-to-cook clam products (Malvani masala & Kohlapuri masala) were standardized and kept for storage under refrigerated conditions.


*Fig 1. Control, Malvani masala, Kholapuri masala*

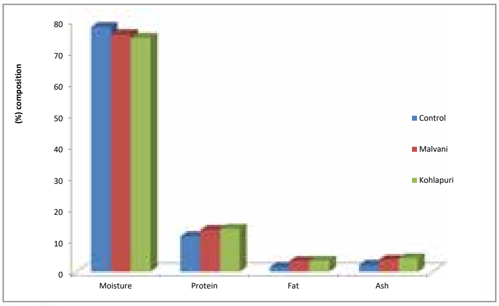


*Fig 2. Nutritional profiling of three groups of RTC Clam*

The nutritional composition was studied for the three groups where the moisture varied from 74.56 ± 0.57 to 78.06 ± 0.63, protein varied from 11.41 ± 0.28 to 13.75 ± 0.54, fat content varied from 1.52 ± 0.79 to 3.53 ± 0.17 and ash content varied 2.16 ± 0.37 to 4.3 ± 1.10 within the control and treatment groups. Storage study was completed where in Control group spoiled by the 15th day, the Kholapuri masala group spoiled by the 16$^{th}$ day and the Malvani masala treated group spoiled by the 18th day of storage under refrigerated condition.

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# *Macronutrient and mineral profiling of Tegillarca granosa (blood clam) sourced from Vashi Creek, Navi Mumbai, Maharashtra, India*

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India is one of the 193 member states of the United Nations that is a signatory to the UN's Agenda 2030 which has at its core a set of 17 Sustainable Development Goal (SDGs) of which SDG 2 on Zero Hunger calls for ending all forms of hunger by year 2030 (UNSDG, 2017). Deficiency arising due to lack of intake of micronutrients causes micronutrient malnutrition also referred to as hidden hunger. According to WHO, more than 2 billion people suffer from hidden hunger and it is a worsening challenge worldwide (FAO, IFAD, UNICEF, WFP and WHO, 2021). Though required in minute quantities, their deficiency causes serious, sometimes life-threatening health conditions. Also, micronutrient deficiencies (MiND) may cause more subtle effects like fatigue and low mental clarity resulting in compromising of critical development outcomes like reduced growth, increased susceptibility to disease, exacerbation of illness, and an overall decrease in work efficiency and capability.

Globally, iron deficiency is one of the most commonly occurring MiND with WHO estimating that 0.5 billion women between ages 15 to 49 and 269 million children between ages 6-59 months are anemic, followed by zinc and iodine deficiencies (WHO, 2021). Worldwide, 1.8 billion people suffer from iodine deficiency and about 30% of people are at risk of zinc deficiency due to inadequate intake. MiND rates are significantly higher in South Asia and Sub-Saharan Africa; for instance, anemia affects over 60% of the population in some countries. According to a study by the Consumer Health Division of Bayer over 80% of Indians suffer from MiND (Consumer Health Division of Bayer, 2022). More than half of women of reproductive age, i.e. about 57% in India suffer from iron deficiency anemia according to National Family Health Survey (NFHS)-(V) and 32% and 3.9% of adolescents have zinc and iodine deficiencies respectively (MoHFW, 2021).

While the status quo regarding MiND seems dismal, ailments associated with MiND can be easily prevented through nutrition awareness creation, intake of healthy, diverse, and nutrient-dense foods, food fortification and supplementation of nutrients. While these strategies have contributed to a significant reduction in rates of MiND globally as well as in India, more concerted efforts are essential for the achievement of SDG 2. Seafood including fish and shellfish contains good quality, readily digestible protein, minimal fat that is rich in healthy omega 3 fatty acids, vitamins like D & B2 and minerals including iron & zinc with clams being advocated as particularly good sources of iron.

Clams thrive in marine environments in addition to fresh water and brackish water habitats and are by far the most prolific and extensively occurring bivalves. They form an important part of the sustenance fisheries of coastal fishing villages and are crucial for both their nutritional needs and economy. Abundant beds of *Tegillarca granosa* or *Anadorra granosa* commonly called blood clams, due to the occurrence of blood red hemoglobin pigment, occur alongside the southwest coast of Maharashtra. *T. granosa* forms a crucial part of local fisher-folk diets providing them with affordable nutrition in terms of protein and minerals meeting a vital part of their daily nutritional needs. This paper describes the proximate composition analysis and mineral profiling of fresh blood clams collected from Vashi Creek, Navi Mumbai.

The meat was shucked out of clam shells soon after harvest and 200 g of edible portion was immediately iced and transported to Mumbai Research Center, ICAR-CIFT, Vashi for the study. Clam meat was minced and used for the proximate composition analysis (protein, moisture, fat and ash), using standard AOAC Official Methods of Analysis 2015, 18$^{th}$ Edition (AOAC, 2015). Briefly, for estimating moisture content, 10g of clam samples were subjected to drying at 120 °C for 2 hr or until a constant weight was obtained. About 0.1 g of homogenized clam meat was acid digested, distilled and titrated to determine the crude protein using the Kjeldahl method (Nitrogen value X 6.25 conversion factor). The crude lipid content of clam samples (5g) was determined by continuous soxhlet extraction of lipid with petroleum ether. AOAC method (AOAC, 2015) for mineral profiling constitutes microwave acid digestion followed by quantitative determination by ICP-OES which was done at the Quality Assurance and Management Division of ICAR-CIFT, Cochin. Analysis was carried out in triplicates and values were expressed as mean ± standard deviation.

Information on the organic chemical constituents of foods is vital as the nutritive value is reflected in their biochemical content. Chemical composition is a reflection of the physiological state of the animal, the availability of food and factors related to the habitat. The proximate composition of blood clams is given in Table 1. Blood clams show a significant amount of protein 13.3% and their nutritive value comes not only from the high quality of protein but also the relatively low-fat content (1.54 %) and the significant level of ash content of nearly 2%. Typically, fish contain negligible carbohydrate content, but contents in shellfish are reported to vary from nearly 1 to 10% (Karnjanapratum et al., 2013) and blood clams showed 3.49 % of carbohydrates.

*Table 1. Macronutrient composition of blood clams Tegillarca granosa collected from Vashi Creek, Navi Mumbai, Maharashtra*

| S. No. | Macronutrient | Percentage* |
|---|---|---|
| 1. | Moisture | 79.74±1.3 |
| 2. | Protein | 13.30±1.1 |
| 3. | Fat | 1.54±0.3 |
| 4. | Carbohydrate (by difference) | 3.49±0.6 |
| 5. | Ash | 1.93±0.3 |

**Values are expressed as the mean of three determinations ± standard deviation*

The concentrations of the various minerals determined in the edible portion of the blood clams is shown in Table 2. Among the microminerals detected in the blood clams, Fe and Zn show the highest quantities followed by Mn, Cu, Ni, Se, Mo and Co. The exceptionally high content of Fe of nearly 1g/kg make blood clams an excellent source of Fe. This may be as a result of the blood pigment hemoglobin that is dispersed in the blood and tissues imparting red color to the muscle (Mohite S. and Meshram A.M., 2015). Anemia, which occurs due to deficiency of iron, is a condition where an individual's blood lacks enough red blood corpuscles for efficient transport of oxygen. Iron deficiency is a consequence of low dietary intake or decreased absorption arising due to poor bioavailability of iron. Bioavailability is a function of several factors like the type of iron; it being heme or non-heme type, presence of enhancers (like vitamin C) or inhibitors (like phytates) in food. With this viewpoint, it is important to evaluate blood clams for their potential to provide bioavailable iron. Nonetheless, the inclusion of blood clams in diets of populations, vulnerable to insufficient iron intake like adolescent girls at least thrice a week may be a useful strategy to address iron deficiency. Zn, though a trace metal is a vital part of over 300 enzymes that catalyze diverse reactions in metabolic pathways influencing cell growth, cell division, immunity, wound healing etc. Zn deficiency symptoms include growth retardation, immune dysfunction and cognitive impairment (Prasad, 2013). Blood clams showed Zn levels of nearly 90 mg/kg and the RDA for Zn ranges from 8 to 12 mg (Koe, 2021). In this context, a serving size of 100 g of blood clam would fulfill the daily requirement of Zn. Similarly, Mn, Cu, Ni, Se, Mo and Co are trace elements with important physiological roles in humans and are present in significant quantities in blood clams.

Among the macrominerals in blood clams, Ca and P levels were found to be over 10g/kg indicating that clams are a good source of these minerals. Ca and P together are essential for healthy bones and teeth and are the main components of hydroxyapatite, the bone mineral that gives strength to the organic matrix. Men and women of all ages are susceptible to Ca deficiency which reduces bone strength leading to osteoporosis, characterized by fragile bones while deficiency of P causes osteomalacia and rickets in addition to conditions like anemia and low mental clarity. K (7g/kg) and Mg (2g/kg) are both essential for optimal function of the heart and muscles and are important for metabolic pathways as they are constituents of enzymes. Deficiency as a result of low intake though rare is characterized by arrhythmia, fatigue and muscle weakness.

*Table 2. Macro and micro minerals in blood clams Tegillarca granosa collected from Vashi Creek, Navi Mumbai, Maharashtra*

| S. No. | Mineral | Concentration* |
|---|---|---|
| | **Macrominerals** | **(g/kg)** |
| 1. | Calcium (Ca) | 10.97±0.8 |
| 2. | Magnesium(Mg) | 2.13±0.1 |
| 3. | Phosphorous(P) | 10.22±0.5 |
| 4. | Potassium (K) | 7.27±0.3 |
| 5. | Sodium (Na) | 6.52±0.6 |
| | **Microminerals** | **mg/kg (ppm)** |
| 6. | Copper (Cu) | 7.94±0.4 |
| 7. | Cobalt(Co) | 0.94 ±0.04 |
| 8. | Manganese(Mn) | 29.87±1.4 |

| | | |
|---|---|---|
| 9 | Molybdenum | 1.10±0.06 |
| 10. | Iron (Fe) | 978.92± 32 |
| 11. | Nickel (Ni) | 4.41±0.6 |
| 12. | Selenium (Se) | 3.75±0.25 |
| 13. | Zinc(Zn) | 89.90± 3.7 |

*⁎Values are expressed as mean of three determinations ± standard deviation*

In conclusion, blood clams can be referred to as a storehouse of macro and micro nutrients essential for proper functioning of the human body and incorporating them regularly in diets will help meet daily requirements of these nutrients. With India striving to achieve the agenda 2030 of the UN, addressing MiND is very crucial and regular consumption of blood clams especially by people where it is a local fishery can contribute substantially to achieving this significant milestone.

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# *Heavy metal content in dry fish sold in domestic markets of Navi Mumbai, Maharashtra*

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Heavy metals originating from both industrial sources and anthropogenic sources have a long environmental persistence with properties of bio-accumulation and biomagnification through food chain. Among heavy metals, cadmium (Cd), mercury (Hg), lead (Pb) and arsenic (As) are known for their severe toxic effects in living organisms. Cd is considered as seventh most toxic non-essential heavy metal. Smelting, production of nonferrous metal, iron and steel production, disposal of Cd-containing materials, herbicides, and plastic stabilizers are the main source of Cd accumulation in the environment. Mercury is the most toxic heavy metal found in the aquatic environment. Combustion of fossil fuel is the major source of Hg. The most toxic and common Hg compound in the marine aquatic food chain is methylmercury. Although industrial disposal of Hg is reduced due to an increase in awareness among the public, the environmental Hg level is still on the higher side. Mining, Smelting, metal water pipes, and paints are the source of Pb. Most reported Pb species in marine organisms include inorganic lead, and tri-methyl lead. The main target organism of Pb poisoning include the digestive system, bones, kidney, reproductive system and immunologic system.

Dried fish form part of 20% of the total fish production in India (Anon, 2016) and it is higher than the global average of 12% (FAO 2018). Considering the acceptance of dried fish and dried fish-based products among consumers, a study on heavy metal content in dried fish and shrimp samples collected from domestic markets of Navi Mumbai, Maharashtra was carried out. A total of 42 numbers of dried samples were collected including 26 fishes and 16 shellfishes. The content of As, Cd, Pb, and Hg in the samples was evaluated using Inductively Coupled Plasma Photometer, ICP-OES (ICAD 6300 Duo view, Thermofisher, USA).

Heavy metal content in dried fish samples is given in Table 1. In 20% of the samples high content of Cd was detected in samples of dried cuttlefish (5.79mg/kg), dried Acetes samples (5.2 and 7.2mg/kg), and dried golden anchovy (3.65mg/Kg). As per FSSR (2011), the limit for cadmium in crustaceans is 0.5mg/kg, in bivalves 2mg/kg and in fish is 0.3mg/kg. Cd can be accumulated with metallothioneins and uptake of 3 – 330mg/day is toxic and 1.5 - 9mg/day is lethal to humans (Mansouri et al. 2013). Cd harms kidneys and leads to symptoms of chronic toxicity such as impairment of kidney function, poor reproductive capacity, hypertension, tumours and hepatic dysfunction (Waalkes et al. 2000). As per FSSR (2011) permissible limit of Pb in fish is 0.3mg/kg. In the present study, 12% of the samples contained high levels of Pb in dried ribbon fish (2.86mg/kg) has a higher content of Pb. Dried Acetes and dried shrimp contain trace amounts of Pb in the range of 0.003-0.33mg/kg. Exposure to Pb may cause nervous system damage, paralysis and pain in the extremities. Hg content was not detected in any of the dried fish samples analysed under the study. As is present in almost all samples. Its concentration ranges from 0.43 to 53.45mg/Kg. For fish and crustaceans, the limit of As as per FSSR (2011) is 76mg/kg. Higher content of As was observed in dried shrimp and dried Anchovy at levels of 52.8 and 53.45 mg/Kg respectively. The accumulation of heavy metals in fishes depends mainly on the bioavailability of metals in habitat and habits, ecological needs, metabolism, age, size and processing. The metal contamination level of dried fish from domestic markets of Navi Mumbai indicated the higher presence of Cd and Pb which can be through contamination by industrial sources. This calls for stringent control of the processing and drying systems as well as regulatory measures for protecting the health of the consumers.

*Table 1. Heavy metal content in dried fish collected from domestic markets of Navi Mumbai*

| Sl. No. | Sample Name | No. of Samples | Cd | Pb | Hg | As |
|---|---|---|---|---|---|---|
| 1 | Penaeid Shrimp | 2 | (0.14±0.0-0.26±0.01) | ND | ND | (7.97±0.06-8.35±0.15) |
| 2 | Ribbon Fish | 6 | (0.05±0.0-0.22±0.0) | (0.22±0.01-5.5±2.08) | ND | (1.46±0.03-2.7±0.11) |
| 3 | Seer Fish | 1 | ND | ND | ND | ND |
| 4 | Acetes | 7 | (0.03±0.0-7.2±0.10) | (0.24±0.01-0.33±0.03) | ND | (1.36±0.12-12.9±0.10) |
| 5 | Bombay Duck | 6 | (0.03±0.0-0.06±0.0) | ND | ND | (0.5±0.10-2±0.10) |
| 6 | Golden Anchovy | 4 | (0.17±0.0-3.65±0.24) | ND | ND | (1.73±0.07-2.83±0.06) |
| 7 | Anchovy | 6 | (0.13±0.0-0.2±0.0) | ND | ND | (1.31±0.09-53.45±1.7) |
| 8 | Shrimp | 4 | (0.14±0.0-0.21±0.0) | (0.003±0.07-0.002±0.09) | ND | (5.3±0.06-52.8±0.57) |
| 9 | Cuttle Fish | 1 | 5.79±0.01 | ND | ND | 16.6±0.10 |
| 10 | Indian Anchovy | 1 | 0.15±0.00 | ND | ND | 1.11±0.09 |
| 11 | Tiny Shrimp | 2 | (0.05±0.0-0.12±0.0) | ND | ND | (10.25±0.10-22.8±0.25) |
| 12 | Mackerel | 1 | 0.06±0.00 | ND | ND | 0.43±0.02 |
| 13 | Cat Fish | 1 | 0.021±0.00 | ND | ND | 3.9±0.09 |
| | Total | 42 | | | | |

**Values are given as a range (mean ± Standard deviation) in mg/Kg*

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# *Phosphorus Level in Wild-Caught Shrimps of Kerala Coast*

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Phosphorus is an essential mineral, which is abundantly present in the human body contributes to around 1% of the total body weight (Calvo & Lamberg-Allardt, 2015). Phosphorus plays a major role in the metabolism of carbohydrates and sugars. It helps to keep the bone, teeth, and muscles strong, and ensure proper muscle contraction, kidney function, and heartbeat regulation. Foods that are rich in protein and calcium also serve as a rich source of dietary phosphorus. Seafood is considered one of the excellent sources of dietary phosphorus along with chicken, egg, milk, cheese, seeds, nuts etc.

In the present study, the natural level of phosphorus was determined in 8 commercially important wild-caught shrimps such as *Metapenaeus dobsoni* (flower tail prawn), *Penaeus semisulcatus* (green tiger prawn), *Parapenaeopsis stylifera* (kiddi shrimp), *Fenneropenaeus indicus* (white prawn), *Heterocarpus gibbosus* (humpback nylon shrimp), *Metapenaeus monoceros* (speckled shrimp), *Penaeus monodon* (giant tiger prawn), and *Macrobrachium rosenbergii* (giant river prawn). The samples were collected from different landing centres of Ernakulam & Alappuzha districts of Kerala and brought to the laboratory under iced conditions. The meat was collected and homogenized for analysis. Analysis of total phosphorous content was carried out using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). The protein content was estimated according to AOAC 928.08.

It was found that all the shrimp species were having high amounts of phosphorous, ranging from 1801.53 mg/Kg to 2924.12 mg/Kg. The highest content was found in *P. semisulcatus*, and the lowest in *M. dobsoni*. Studies conducted by Yanar et.al., (2011), Samantha Nichole Stein (2014), and Dayal et.al.,(2013) also reported high content of phosphorus in various shrimp species viz., *P. semisulcatus* (2444.6 mg/Kg), *Litopenaeus setiferus* (2211.76mg/Kg to 4697.03mg/Kg), *P. monodon* and *F. indicus* (3034 mg/Kg -average value for *P. monodon* and *F. indicus*)

The total Phosphorus - to Protein Ratio (PPR) of different species of shrimp was found to vary from 8.67 to 16.14 mg/g. The lowest PPR value was found in *P. stylifera* while the highest value was found in *F. indicus*. Guillermina Barri-Cuadrado et al., (2013) also reported a PPR value of 9.58 to 10.22 mg/g for shrimps; the reference PPR value for crustaceans is 10.61mg/g (Dusek et al., 2003, Teixeira et al., 2017).

The present study of the natural level of phosphorus and phosphorus to protein ratio of different species of shrimps indicates that shrimps are having high and favorable PPR values for the general population as well as people with certain disease states such as chronic kidney disease (CKD).

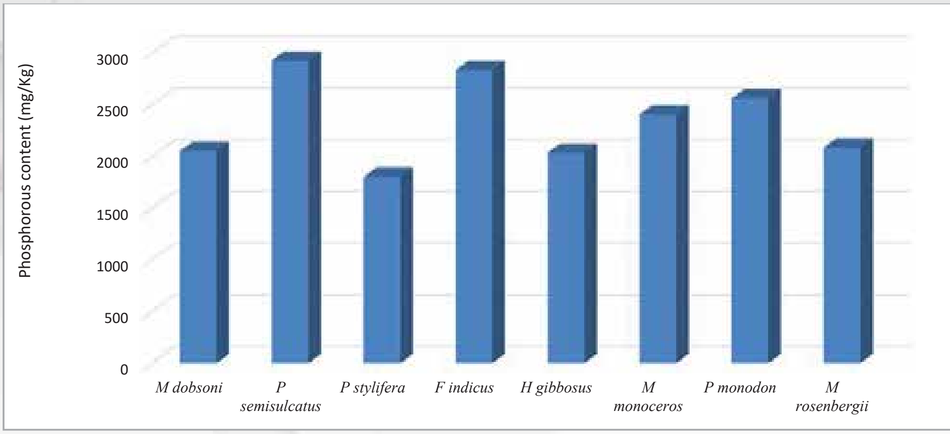


*Fig 1. Total phosphorus content in different species of shrimps*

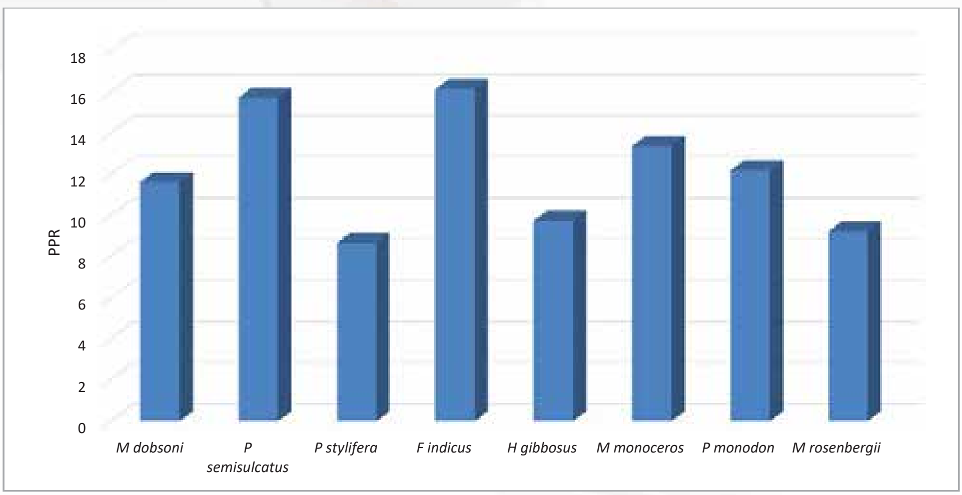


*Fig 2. Phosphorus to protein ratio (PPR) of different species of shrimps*

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# *Cephalosporin resistance: A predominant antimicrobial resistance found in E. coli isolated from Vembanad and Sasthamkotta Lake, Kerala*

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In recent years, antimicrobial resistance (AMR) has become a hazard to humans and other animals, and the health sector is now experiencing an upsurge in AMR in lakes and other water bodies which supply drinking water to the common public. Antimicrobials are employed in human health and animal agriculture; as a result, aquatic habitats become "a hot reservoir and carrier of AMR genes" (Watts et al. 2017).

Surveillance is an important aspect of any mitigation measures. The first step in controlling the growing AMR throughout the system is to produce evidence using a surveillance strategy. The Vembanad Lake in Kerala, India, is regarded as the longest Lake in India (96 km), as well as the largest Lake in the State. It is an open complex wetland system, and the lake receives water from six major rivers (Vaiyapuri et al., 2021). The Sasthamkotta is the largest freshwater closed lake in Kerala supplementing the drinking water needs of the Kollam region and hence ensuring the quality of the water assumes significance.

*E. coli* is regarded as the primary faecal indicator bacteria used to test the quality of food and water (Visnuvinayagam et al., 2017), and the AMR of *E. coli* is on the rise globally. This is a concern as more ESBL and carbapenemases are being produced with greater resistance. Therefore, evaluating these two aquatic bodies for both the microbiological quality and the AMR was deemed essential for determining the current state and creating mitigating plans.

A surveillance study was conducted across Vembanad Lake and Sasthamkotta Lake. For the Vembanad Lake, water samples (n=35) were drawn from different geographical locations over the entire 90Km stretch of the Lake. The antibiotic susceptibility test (AST) was performed on 116 *E. coli* isolated from 27 (77.1%) positive samples. For the Sasthamkotta Lake, water samples were collected from 16 sites using a Niskin water sampler machine. The water was directly collected in a sterile bottle and kept chilled until further laboratory use. *E. coli* was isolated from the water samples from 11 sites, and AMR was determined. The study has identified the prevalence of *E. coli* in both the lake water samples. The probability of isolating cephalosporin-resistant *E. coli*, particularly cefotaxime-resistant *E. coli*, was the highest in both the Lake.

The two most dangerous resistances emerging in cephalosporin medicines are extended spectrum beta lactamases (ESBL) and carbapenem resistance. Cephalosporin resistance including ESBL E. coli was reported in the first surveillance study at Vembanad Lake, Kerala (Vaiyapuri et al., 2021), rivers and lakes in Northwest China (Liu et al., 2018), rivers and lakes in Switzerland (Zurfluh et al., 2013), Jurong Lake, Singapore (Zhong et al., 2021), urban lakes and reservoirs in Southeastern Brazil (Nascimento et al., 2017). Cephalosporin resistance, particularly third and fourth generation cephalosporin resistance, is already recognised as a hazard to the public health system, and this issue has been observed in other sectors such as food animal production and the environment.

The study indicates that more cephalosporin antibiotics are being used across sectors, and finally, the water bodies are at the receiving end. In the one health context of mitigation measures for AMR, enough emphasis should be given to the environmental component of one health.

**Acknowledgement:** The authors are thankful to the Director, ICAR-CIFT, for funding the research and staff of the MFB division for rendering technical support during sampling and analysis.

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# Biochar from seaweed: A sustainable tool for ensuring the microbial water quality from the seafood industry

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The seafood industry is upcoming as a fast-paced growing sector around the world for the past few decades. Worldwide, seafood consumption increased drastically as a healthy choice of animal protein with enhanced nutritional quality in terms of easily digestible proteins, poly-unsaturated fatty acids and various vitamins and minerals. Indian seafood production indicates 21-fold growth in the last seven decades with an average annual growth rate of 10.88% and ranks second after China with an export quantity of 1.4 mmt worth 7.76 billion US dollars (SOFIA, 2022). Seafood processing is an industry which has a substantial requirement of water. (Tomsczak-Wandzel et al., 2015). Positives apart, seafood water footprint and pollution remain as significant stand-out challenges among various seafood industry-related issues. A large volume of wastewater is generated from the seafood industry. Almost all steps in the seafood industry require water; from preprocessing (raw material washing, cleaning), processing (freezing, thawing, cooking, brine preparation, glaze preparation), and post-processing (Storage and transportation) (Murali et al., 2021). In addition, water is used in large quantities to maintain hygienic conditions such as equipment and floor cleaning, proper toilet and washing facilities, foot and hand dips etc (Henriksson et al., 2018). According to the Export Inspection Council (EIC) of India, on average, a minimum of 10 L of water is necessary to process 1 kg of fish (EIC, 2005). As water is a finite source, wise usage is always necessary. Minimization of water usage and reuse of water after proper treatment is necessary to overcome the expected water shortage.

Biochar is a charcoal-like carbonised form of biomass (grass, agricultural and forest residues) formed by pyrolysis under controlled conditions (Vijay et al., 2021). Generally, biochar act as a soil conditioner possessing properties like water retention, nutrient retention, and stable storage of carbon (Murtaza et al., 2023). In addition, biochar also holds large adsorption surfaces with different functional groups which can capture and filter water pollutants including heavy metals. Therefore, switching from conventional to green-safe methodologies like biochar-aided water treatment is of great advantage not only to the industry but also to the environment. Therefore, this study evaluates the efficiency of biochar developed from seaweed in the treatment of wastewater generated from the seafood industry.

Wastewater samples from the seafood industry of Taloja, Navi Mumbai region were collected aseptically in sterile bags. Biochar from brown seaweed Sargassum wightii was prepared according to Rehana et al., 2023. Water samples were enriched in trypticase soy broth (TSB) and biochar was added at different concentrations from 1% to 10% followed by incubation at 37˚C for 24 h. To evaluate the initial viable microbial load, all the test samples were subjected to total plate count studies by plating 0.1ml of serial dilution from $10^{-1}$ to $10^{-13}$ prepared in normal saline over plate count agar (PCA). The plates were further incubated at 37˚C for 42 hours (BAM Method). Similarly, the total viable count of the enriched treatments from T0 to T7 was also carried out. After incubation, plates with 30-300 colonies were selected for the expression of viable bacterial count. Results were expressed in CFU/g.

In this study, it was found that biochar developed from brown seaweed Sargassum wightii could remove microbial contamination at a 10 % incorporation level (Figure 1 and Table 1). The clear water after treatment in this study reveals that seaweed-based biochar is highly effective in water clarification by filtering and adsorbing (Figure 2). Therefore, seaweed-based biochar developed from Sargassum wightii can be adopted as a suitable eco-friendly method for treating wastewater developed from the seafood processing industry. Further studies are required to understand the impact of seaweed-based biochar on water quality along with other existing and emerging water quality amendment practices.

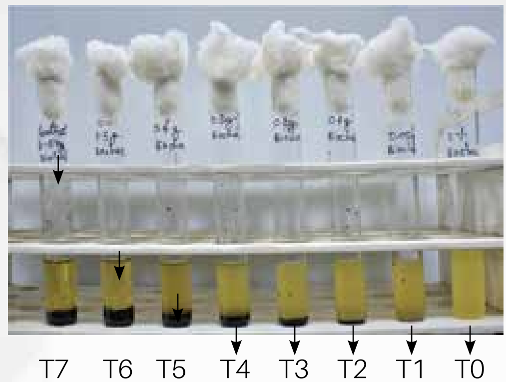


*Fig 1. Change in visible turbidity in different treatments from T7 to T0*

*Table 1. Average bacterial load at different treatment conditions*

| Sl No | Treatments | Conditions | Average viable count in CFU/g |
|---|---|---|---|
| 1 | T0 | Control (5ml TSB + 500µl waste water) | TNTC |
| 2 | T1 | 5ml TSB + 500µl waste water+ 0.05g biochar | TNTC |
| 3 | T2 | 5ml TSB + 500µl waste water + 0.1g biochar | TNTC |
| 4 | T3 | 5ml TSB + 500µl waste water + 0.2g biochar | $1.9 \times 10^{3} \pm 0.03$ |
| 5 | T4 | 5ml TSB + 500µl waste water + 0.3g biochar | $6.8 \times 10^{2} \pm 0.03$ |
| 6 | T5 | 5ml TSB + 500µl waste water + 0.4g biochar | $2.3 \times 10^{2} \pm 0.04$ |
| 7 | T6 | 5ml TSB + 500µl waste water + 0.5g biochar | Less than 10 |
| 8 | T7 | 5.5 ml TSB + 0.5g biochar | Nil |

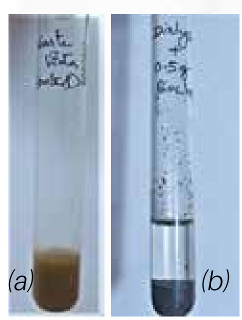


*Fig 2. Turbidity reduction in waste water without biochar (a) and with 0.5g biochar (b)*

# *Liquid chromatography-based method for estimation of colour additives in fishery products*

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Colour is the primary perception which plays a significant role in the purchase of food commodities. In fact, the consumer also associates the colour of a food product with its taste and their storage condition. These generate a certain product expectation for consumer acceptability (Derndrofer and Gruber, 2017). The artificial colour additives are not nature-identical but are chemically synthesized. The colour additives are added to food to compensate for the colour losses due to the effect of light, temperature, air and moisture. Artificial colour additives are generally preferred over their natural counterparts because of inherent advantages like stability, availability, cost, efficacy, etc. However, due to the consumer's health concerns such as allergenicity, behavioural disorders, neurotoxicity, genotoxicity, and carcinogenicity associated with their consumption (Corradini et al. 2018), synthetic food colours are governed by regulatory limits. Hence, their determination becomes very critical. Food Safety and Standards Regulations (FSSR, 2011) has authorized the use of the following colour compounds in fish and fishery products such as Allura Red, Brilliant Blue, Fast Green FCF, Indigo Carmine, Ponceau 4R and Sunset Yellow FCF. Petigara Harp et al. (2013) developed a chromatographic method for the estimation of FDA-certified colour additives viz., Brilliant Blue FCF, Indigo Carmine, Fast Green FCF, Erythrosine, Allura Red AC, Tartrazine and Sunset Yellow FCF using a reversed-phase C18 column. The colour additives were resolved by mobile phase consisting of ammonium acetate in water and methanolic ammonium acetate in gradient elution mode. The detection was carried out at 420, 520 and 620 nm. The complete separation of colours took 47 minutes. Keeping this in mind, an attempt was made towards developing a liquid chromatography-based method for the estimation of FSSAI-approved food colour additives in fish and fishery products. The chromatographic separation of the colour in the standards was achieved by reversed-phase C-18 column using a mobile phase mix consisting of ammonium acetate and 90% methanol in gradient mode at a flow rate of 1 ml/min. The detection was carried out at a single wavelength of 254 nm. The protocol (Table 1) gave efficient separation of the colour additives present in the standard solution in less than 24 minutes (Fig. 1). The method developed is efficient in saving time as well as the amount of solvent used for separation. The method is being validated for parameters viz., linearity, range, repeatability, reproducibility, limit of detection and quantitation, and the method developed shall be applicable for the determination and quantitation of approved colours in fish and fishery products.

*Table 1. The elution time of various colour additives*

| Sl No. | Analyte | Additive No. | Class of dye | Chemical Name | Retention Time (min) |
|---|---|---|---|---|---|
| 1 | Allura Red * | 129 | Azo | Disodium 6-hydroxy-5-[(2-methoxy-5-methyl-4-sulfophenyl) azo]-2-naphthalenesulfonate | 15.1 |
| 2 | Brilliant Blue * | 133 | Triarylmethane | Disodium salt of alpha 4-(N-ethylbetaulfobenzylamino)-phenyl] alpha [4-(N-ethyl-3 Sulfonatobenzylimino] cyclohexa-2, 5-dienylidene] toluene-2-sulfonate | 17.8 |
| 3 | Erythrosine | 127 | Xanthene | Disodium or dipotassium salt of 2',4', 5', 7', tetraiodo- fluerescein | 23.3 |
| 4 | Fast Green * | 143 | Triarylmethane | Disodium salt of 4-[4-(N-ethyl-p-sulfobenzylamino)-phenyl-(4-hydroxy-2-sulphonumphenyl)-methylene]-(N-ethyl-N-p-sulphobenzyl 2, 5-cyclohexadienimine) | 17.5 |
| 5 | Indigo carmine* | 132 | Indigoid | Disodium Salt of indigotine-5, 5'-Disulphonic acid | 4.0 |
| 6 | Ponceau 4R* | 124 | Azo | Trisodium salt of 1-(4-sulpho-1-naphtylazo) naphthol-6, 8-disulphonic acid | 11.7 |
| 7 | Sunset Yellow* | 110 | Azo | Disodium salt of 1(4-sulphophenylazo) 2-napthol-6-sulphonic acid | 13.4 |
| 8 | Tartrazine | 102 | Azo | Trisodium salt of 5-hydroxy-1-p-sulphopheny1-4-(p- sulphophenylazo) pyrazol-3-carboxylic acid | 8.4 |

**Approved for usage in fish and fishery products as per FSSR 2011*

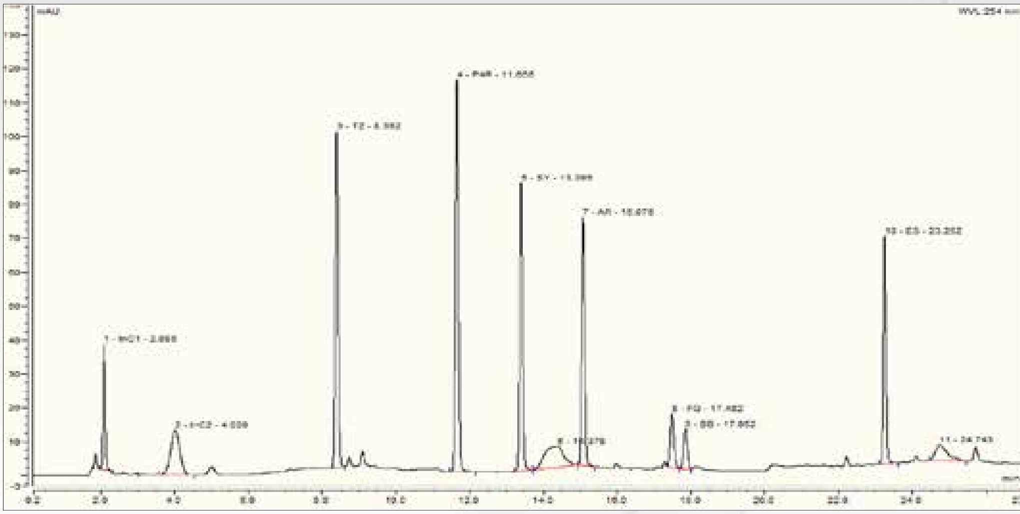

*Fig 1. Chromatogram displaying the peaks for various colour additives at 254 nm (InC - Indigo carmine; TZ – tartrazine; P4R - Ponceau 4R; SY – Sunset yellow; AR – Allura Red; FG – Fast Green; BB – Brilliant Blue; ES – Erythrosine).*

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# Data Summarization of Import and Export Trade of Fishmeal in India

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Fish meal production in India is a significant industry that utilizes forage fishes, by-catches, and processing waste to produce non-edible products primarily intended for export markets. In India, there are more than 40 fish meal producers well equipped for the export market including European countries. The west coast of India, especially Karnataka, is a hub for fish meal processing establishments. This industry plays a crucial role in meeting the protein needs of aquaculture and poultry production in India and beyond.

Globally, the exchange of fishmeal is happening through the import and export trade under the Harmonized System (HS) code HS- 230120, which is sub-HS code under HS-2301. To understand the pathway of import and export trade of fish meal in India under the head HS- 230120, secondary data on the import and export of fishmeal to and from India under specific HS codes were collected from the COMTRADE, a database (https://comtrade.un.org/) maintained by United Nations, for the period 2000 to 2019.

The normalized trade balance index for fishmeal was computed using the Equation (1) to see the import trade performance of fish meal and pellets under the head HS-23012 over export trade performance.

$$Z_t = (E_t - I_t)/(E_t + I_t), \ -1 \leq Z_t \leq 1 \ .........(1)$$

where $Z_t$ is the normalized trade balance of fishmeal at time t

## Import of Fish Flours, Meals and Pellets: HS - 230120

India imports flours, meals, and pellets of fish and aquatic invertebrates categorized under HS-230120 of HS-2301. The imports witnessed significant growth until 2004, followed by a steep decline until 2008, and thereafter remained stagnant up to 2014 before increasing again. The highest import quantity, around 44,800 tons valued at 35 million USD, was recorded during 2003-2005. In 2019, the import quantity was 14,732 tons valued at 19.02 million USD. Key suppliers are Chile, China, Norway, Oman, Peru, Thailand, UAE, Malaysia, Mauritania, and Morocco. Initially, Peru and Chile were the major suppliers, later replaced by Norway, Oman, and the UAE.

## Export of Fish Flours, Meals and Pellets: HS - 230120

From 2000 to 2019, India's fishmeal exports, classified under HS-230120, experienced significant growth. Starting at less than 1000 tonnes, it reached 77,599 tonnes, valued at 79 million USD in 2019. This exponential increase began in 2013. Key importers of Indian fish meal included Bangladesh, Vietnam, Thailand, Saudi Arabia, Malaysia, and China, collectively making up nearly

80% of total exports. The demand was driven by South-East Asian countries due to increased aquaculture production. The majority of fishmeal in aquaculture feeds was consumed in Asia, with 34% in China, in 2019.

The trade balance data reveals that India was a fishmeal importing country in terms of quantity up to 2010, but it later shifted to being an export-oriented country in this regard. This shift can be attributed to the increasing demand for Indian fish meal from South-East Asian nations, driven by the growth in aquaculture production. Fishmeal production has remained stable and is expected to see slight growth in the future as it continues to be a crucial input for aquaculture.

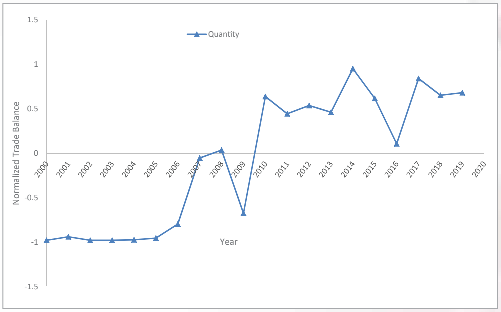

Fig 1. Trade balance data of fish meal

The trade balance data presented in Figure 1 indicates that India has become more self-sufficient in fish meal production, even exporting a significant quantity to South-East Asian countries. Promotion schemes to boost fish production, which in turn supports aquaculture, are in place. However, there are restrictions on establishing new fish meal units for export. This suggests that domestic consumption of fish meal by the feed industry is likely to increase, leading to a potential decline in fish meal exports. Simultaneously, fish meal imports may gradually rise. Unfortunately, there is no reliable data on fish meal consumption in the Indian fish and poultry feed industry. Industries may increasingly turn to raw materials such as fish and shrimp processing waste, especially from the seafood export sector, rather than relying on trash fishes and high-nutrition food fishes like sardines. The lack of specificity in the HS code for fish meal makes data-driven policy decisions in fisheries and aquaculture more challenging.

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# *Distribution analysis of per capita fish consumption among the tribes of Wayanad*

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Kerala is a significant fish-producing and consuming state of India. The fishing industry is important to the state economy. About 1.58% of the state GDP is contributed by the fisheries industry. The state has an elevated fish consumption of nearly 30 kg (NSSO, 2014). But the pattern of fish consumption is not distributed evenly all over the state. Based on the availability and preferences, the fish consumption pattern varies among the regions of the state. The coastal and marine regions are found to have a higher fish consumption than that of the hilly land-locked regions of the state. Wayanad is a landlocked district of Kerala, which has a higher tribal population and data on the fish consumption patterns among the tribes is scanty. The wholesale and retail markets in Wayanad receive fish from the marine landing centres of Kerala, Karnataka, Tamil Nadu, and Andra Pradesh. Minitrucks were commonly used to transport low-value fish such as sardines, mackerels, and tilapia from wholesale and retail markets to the tune of about 100 kg/day of iced marine and freshwater fish on average. (Shyam et al., 2020). The current research was conducted by ICAR-CIFT, Cochin, to investigate the fish-eating patterns of the tribal populace as part of the WorldFish Project. The stratified probability proportional sampling technique was devised to investigate the fish consumption habits of the district's 200 selected tribal households. (Joshy, et al.,2020).

Based on the study 45.5% of the individuals consumed fish once in a week and the per capita fish consumption of the observed tribes was revealed as 1.03 kg/month, less than the state average of 2.5kg/person/month (Sajeev et al.,2021). Most respondents (78%) belonged to an age group of 26-50 years and 78% of them were females. About 84% had 3-6 members in their family and 51% had a primary level of education. The majority (72%) were labourers and 10.5% were dependent on agricultural activities for their livelihoods.

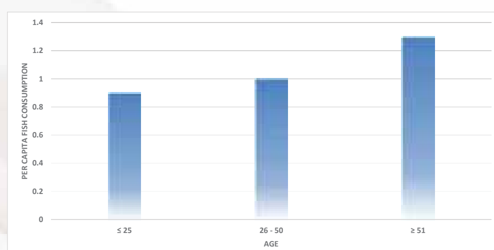


*Fig 1. Distribution of per capita fish consumption vs Age*

The per capita fish consumption of fish differed with age. The age groups below 25 years were found to consume 0.9 kg/month, 25-50 years age group about 1kg/month and 1.3 kg for the age group above 51 years indicating that the fish consumption rate was higher for the age group above 50 years and less among the younger age groups.

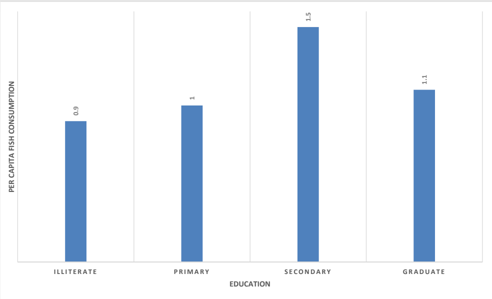


Fig 2. Distribution of per capita fish consumption vs Education

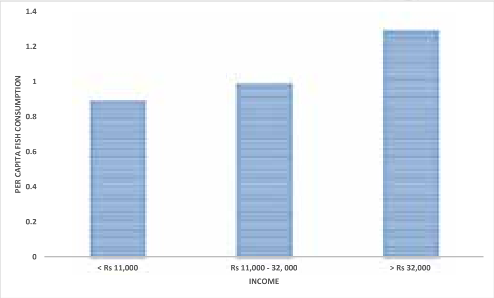


Fig 3. Distribution of per capita fish consumption vs Income

The consumption rate of fish based on the education was assessed and a higher consumption rate was observed among the respondents with a secondary level of education (1.5kg/month) followed by graduate (1.1kg/month), primary (1.0kg/month) and illiterates (0.9kg/month). Especially when they have at least primary education, their consumption rate does not vary much from the average per capita fish consumption.

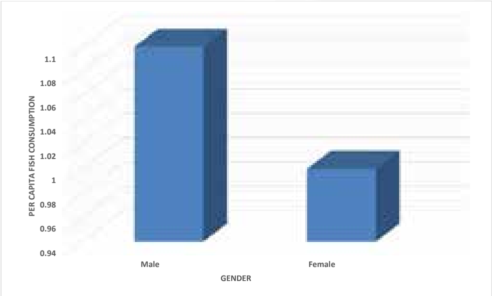


Fig 3. Distribution of per capita fish consumption vs Gender

Based on gender, the result showed that males had marginally higher per capita consumption (1.1kg/month) when compared to that of the surveyed females (1.0 kg/month).

The income of respondents unveiled that the consumption rate of respondents increased as the level of income increased. The per capita fish consumption of respondents with an income rate of above Rs. 32,000 was found to be 1.3 kg/month and those with income below Rs. 11,000 and Rs. 11,000 – Rs. 32,000 was found to be 0.9 kg/month and 1 kg/month, respectively. According to the study of Devi Prasad and Mahadevi (2014), the family income influenced the purchasing behaviour of fish among the respondents. The higher the family income, the higher the portion of fish purchased among the individuals and the average household consumption of fish was 2.86 kg per month. The enquiry also examined the significant factor to consume fish as the freshness of the fish purchased. The study concluded by indicating fish as the highly appreciated food in all income groups mainly due to the easiness in their availability, affordable price, taste, and nutritive value. It was already indicated in a study that age is one of the socio-economic components contributing to fish consumption preferences (Can et al., 2015). The demographic and socio-economic factors determine the fish consumption preferences of the respondents.

## Acknowledgement

The current study has been attempted as the component of ICAR-CGIAR association in India with ICAR-CIFT, Cochin and WorldFish, Malaysia. The aid and recommendation of researchers from WorldFish of CGIAR programme on FISH is acknowledged.


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# *Spatial and temporal variation of women labour in fish vending in Kerala*

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Fish vendors are small-scale sellers of fish and also potential actors in the fish supply chain. They played a significant role in increasing fish consumption in both coastal and landlocked regions. Fish vending is the primary traditional occupation and the only economic means of livelihood for many households. Fish vendors are one of the market functionaries in the fish supply chain who are the viable linkage between producers and final consumers. Fish vendors differ from other market functionaries in terms of convenient time and ease of purchase, all along the way the consumers. They are considered critical from the labourers' point of view, as their work is still considered invisible which really possess a hindrance to bringing uniform policies for fish vendors.

Fish vendors contributed two ways in increasing fish consumption and economic support to the households. There is no proper account of the number of fish vendors in the country for proper management. The majority of fish vendors were women and old aged (above 50 years). Their quality of life is low, highly independent but trapped by the issues of money lenders and are deprived of occupational dignity with decent work. Women fish vendors are relatively sub-standard levels of socio-economic status and they suffer various kinds of neglect and deprivation in terms of work conditions, financial support, transportation facilities and storage facilities. Even though, fish vending is one of the traditional occupations, it is still out of the purview of labour policy, labour laws and regulations.

With this background, a pilot study was conducted with a main focus on labour availability in fish vending in various districts of Kerala, India. The study is based on secondary and primary field-level data. The secondary data across the five years (2014 - 2018) was collected from the publications of the Department of Fisheries, Government of Kerala. Field-level data were used to assess the perception of women fish vendors on their employment in Ernakulam District, Kerala.

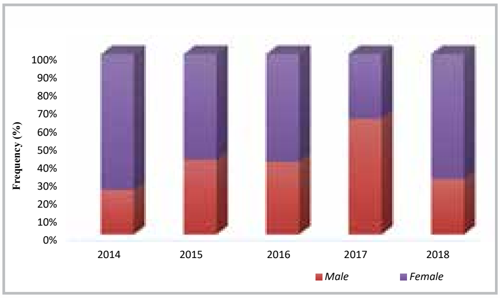
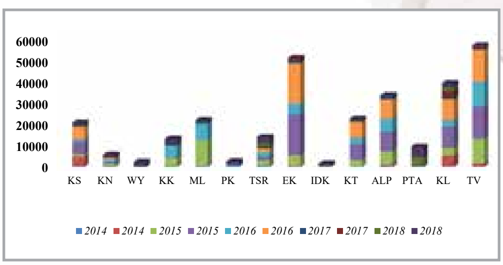



*Fig. 1 Gender-wise fish vendors in Kerala*

The gender-wise fish vendors in Kerala showed that the majority were women (67%) with ages ranging above 60 are maximum. Fish selling is the major source of livelihood for the fish vendors who are the linking force between the production and consumption activities. Their workforce is unskilled and less protective under labour rights and laws.

The temporal data revealed that there is a 78.12% reduction in the number of fish vendors when comparing 2014 to 2018. The number of fish vendors in Kerala was maximum in 2014 and minimum in 2018. The ratio of men and women vendors was maximum (1:3) and minimum (1:0.55) during 2014 to 2017 respectively. This clearly explained the existence of a gender paradox in the fish vending occupation in Kerala. It can be concluded that fish vending is purely a women-dominated occupation.




* *KS – Kasargod; KN – Kannur; WY – Wayanad; KK – Kozhikode, ML – Malappuram; PL – Palakkad; TSR – Trissur; EK – Ernakulam; IDK – Idukki; KT – Kottayam; ALP – Alappuzha; PA – Pathanamthitta; KL- Kollam; TV – Thiruvananthapuram.*

*Fig. 2. District-wise distribution of fish vendors in Kerala*

The spatial data showed that the fish vendors were more concentrated in the coastal districts viz., Thiruvananthapuram and Ernakulam followed by Kozhikode and Alappuzha. And, the minimum number of fish vendors was represented by land-locked districts viz., Pathanamthitta, Palakkad, Wayanad and Idukki.

*Table 1. Perception of fish vendors on their occupation difficulties*

| Particulars | SA | SD |
|---|---|---|
| Productive employment | 34 | 56 |
| Flexible working time | 51 | 32 |
| Balancing work and family | 42 | 36 |
| Income stability | 37 | 52 |
| Safe work environment | 23 | 65 |
| Social security | 26 | 61 |
| Collective bargaining | 21 | 63 |

* *SA-Strongly Agree; A- Agree; N – Neutral; D-disagree; SD-Strongly Disagree*

From the results, it was revealed that in Ernakulam, the majority of the women fish vendors expressed that they were not satisfied with a safe work environment (65%), collective bargaining (63%) and social security (61%) which are considered as pillars of decent employment. Their nature of employment is not so productive and encouraging (56%) and more than

50% of the respondents felt instability in their income. They were agreed on the statements on flexible work time (51%) and able to balance work and family (42%). In general, the vendors are deprived of proper market infrastructure, storage facilities and public transport facilities that are vital for their fish vending activity. A comprehensive framework for the women fish vendors is necessary towards their economic and social upliftment through effective policy initiatives.

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# *Drivers and barriers to online purchase of fish and seafood: A conceptual model*

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Most Indians have a positive perception regarding the consumption of fish and seafood. The annual per capita fish consumption for India's fish-eating population is estimated between 8 to 9 kg. Tripura (25.53kg), Chhattisgarh (19.7kg), Manipur (18.25kg), Kerala (17.93kg) and Odisha (16.34kg) are the bigger states reporting the highest average annual per capita fish consumption while the Union Territory of Andaman and Nicobar Islands reports the highest per capita fish consumption of 77.84kg/year in 2020-21 (DoF, 2022). In India, most fish sale happens through unhygienic local markets, small shops, roadside makeshift stalls and door-to-door vendors. Rampant cases of fish adulteration and quality issues have created a shift in the purchase behaviour of consumers and have helped the emergence and growth of online fish marketing in urban India. Leveraging the possibilities of ICTs and social media, vendors have made online fish retailing possible. This article tries to delineate the drivers and barriers of online fish purchase from consumer angle. The factors identified were consolidated into a conceptual framework of online fish purchase.

## Drivers and barriers to fish purchase and consumption

Personal factors like values, beliefs, attitudes and demographics had a huge influence on fish consumption. Factors like availability, price, market, eating habits, health beliefs, safety and quality concerns and sensory and convenience perception acted as both drivers as well as barriers in varying degrees (Can et al., 2015). An earlier review of the drivers and barriers to fish consumption using 'Theory of Planned Behaviour' as a base provided a framework for quantity, frequency and characteristics of fish consumed (Sajeev et al., 2019).

Studies revealed various factors influencing the purchase and consumption of fish among different communities of India. 'Price of fish' is found emerging as a barrier to fish purchase (Sajeev et al., 2021a) while an often-overlooked factor: 'sensory perception', emerged as an important determinant of fish purchase. The combined effect of 'sensory perception' along with 'availability of dressing facility' and 'convenience perception' has a major contribution to fish purchase and consumption. 'Source of fish (Marine/

Freshwater)' emerged as another important factor followed by 'availability of favourite fish' (Sajeev et al., 2022).

## Drivers and barriers to online fish purchase

Sajeev et al., (2021b) found large urban families recording higher fish purchase and consumption. These urban families were found to spend higher amounts on online fish purchase while attractive monthly incomes among the urban population were found to sustain good expenditure over online fish portals every month. Consumers found online purchase of high- value fish profitable while small pelagic fishes were purchased online mostly for convenience and saving time rather than for any price advantage (Sajeev et al., 2021b).

A specific study attempting to capture the trends in online fish purchase and to delineate the contribution of major drivers and barriers affecting online fish purchase using Conjoint analysis among urban consumers revealed that factors like 'place of origin of fish', '24x7 accessibility' and 'sensory perception' were the most contributing drivers while 'price of fish' and 'availability of favourite fish' were the most important barriers to online fish purchase (Sajeev et al., 2021b).

Fish consumers are exposed to positive information on the nutritional benefits of eating fish while on the other hand they are exposed to negative news of health risks due to adulteration of fish and unscientific post-harvest management. Online portals came up with the guarantee of fresh catch every day from local waters which explains the factor 'place of origin of fish' emerging as an important driver for online fish purchase. Another major driver of online shopping was the option to carry out transactions at any time of the day. Consumers found immense value in online fish shopping due to the provision of dynamic websites and mobile apps, which helped achieve 24x7 accessibility. Hence, '24x7 market accessibility' has emerged as another important factor driving online fish purchase.

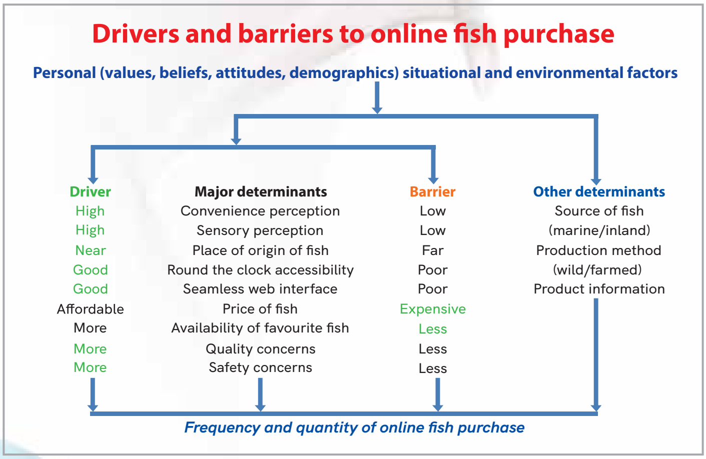


*Fig. 1 Conceptual model of drivers and barriers to online fish purchase*

The present generation of urban consumers being averse towards handling and cleaning of fish, 'Sensory perception' has emerged as an important driver for online fish purchase. The process of purchasing, cleaning and cooking of fish and disposing of fish waste has become a highly time-consuming and cumbersome job for urban families thus making the factors sensory perception, convenience perception, availability of dressing facility and availability of home delivery together act as most important drivers of online fish purchase.

The price of fish online was always found to be 40 to 50% higher than traditional markets and vendors thus not favourable for most of the families for sustained online purchases. The price of fish was found to act both as a driver and barrier according to fluctuations in fish price. Affordable price was found to increase fish purchase and consumption in several Indian locations. The majority of consumers were species-specific while buying fish. Availability and affordability of the most common and favourite fishes; sardine, mackerel, anchovies and pink perch; were poor on major online fish selling portals thus making the factor 'Availability of favourite fish' act as a barrier to online fish purchase.

Seamless web interface along with the increased consumer concerns regarding the safety and quality of fish were other important drivers and barriers to online fish purchase. The source of fish, production method and product information were the other minor determinants recorded. The findings were consolidated into a conceptual model (Fig:1) which can facilitate a better understanding of factors influencing online fish purchases. The model is expected to help refine online fish retailing and assist consumers in making better purchase decisions.

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