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भा कृ अनु प - केंद्रीय मात्स्यिकी प्राद्योगिकी संस्थान
ICAR - CENTRAL INSTITUTE OF FISHERIES TECHNOLOGY
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From the EDITOR'S DESK

The importance of sustainability is evident from the US ban on Indian wild-caught shrimp due to concerns over the stray catch of marine turtles. It is time to re-think about strengthening long term strategies to ensure sustainable use of marine resources. We need to be future ready for the plausible "sustainability challenges" by adopting diverse technological, social and policy innovations. Research conducted by fishery technologists and social scientists continues to advance the goal of sustainable fisheries, ultimately contributing to the sustainable development of nations and communities. Such research initiatives aim to achieve sustainable fisheries and equitable livelihoods by supporting the development, dissemination and adoption of suitable harvest and post-harvest technologies and practices.

This edition of the FishTech Reporter features 12 articles from diverse fields, including quality assurance, antimicrobial resistance, and technologies for reducing food loss. It covers 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, and nanotechnology. Other areas covered include the utilization of secondary raw materials, indigenous technical knowledge (ITKs), local adaptations, and technological interventions in response to the flagship programs of the Government of India.

Managing marine mammals is a challenge to fishermen who are primary producers, in a scenario of increasing reports of catch decline due to coastal dolphins consuming fish that are caught in fishing nets. There is an article that discusses on the interaction of Indian Ocean humpback dolphin with trawl nets.

The articles in this issue include studies on post-harvest technologies focused on maximizing the utilization of fishery resources through modern processing methods, industrial and biomedical applications, the use of secondary raw materials from fishery resources, and nanotechnological innovations.

From the EDITOR'S DESK

The article on using liquid nitrogen (LN_2) as a refrigerant for preserving *Etroplus suratensis* during on-board storage is an effort to reduce post-harvest fish loss, contributing to the goal of sustainable fisheries.

Proactive-approaches in research can support stakeholders in sustaining their income from fish trade and prepare them to be future ready. The study on imidacloprid residue analysis and its withdrawal period estimation in *Macrobrachium rosenbergii* is an effort to support seafood industries to ensure quality and safety of their products.

National plans and programmes play an important role in managing any resource in a country. Government of India through Department of Fisheries, Ministry of Fisheries, Animal Husbandry & Dairying is promoting seaweed cultivation in the country. Value addition of seaweeds, including the development of fermented beverages like 'Kombucha' from brown seaweed, is one among the interventions discussed to promote seaweed cultivation.

Antimicrobial resistance is a growing concern, and the ready reckoner for selecting antibiotic resistance genes (ARGs) will serve as valuable resource for researchers in the field.

Indigenous Technical Knowledge provide solutions to localized problems, and their integration with modern science has proven to be sustainable. This edition also highlights local adaptations in fishing in response to socio-ecological challenges in fishing, the case of 'Ponthu Vallam' in Arthunkal, Kerala.

Finally, **Team FishTech CIFT** is delighted to present these articles to our readers to ignite their thoughts on sustainable fisheries

Contents

Interaction of Indian ocean humpback dolphin, *Sousa plumbea* (G. Cuvier, 1829) with trawler: observation from off the coast of Cochin, Kerala, India

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Marine mammals and their interactions with various fishing systems pose significant conservational challenges worldwide. These interactions have been classified as "direct" or "indirect" depending on their effects on marine mammal species and fisheries socio-economics (Read, 2008). When marine mammals come into contact with fishing gear, they interact directly. These interactions include bycatch, entanglements in fishing gear, and depredation (Read et al., 2006). At the same time, indirect interactions result from fishery-induced ecological changes and resource competitions.

Fisheries play an important role in the socio-economic well-being of India. The country's jurisdictional waters stretches 12 nautical miles across nine maritime states and three union territories. Indian fisheries are multi-species and multi-gear in nature, with a diverse fishery management system and fishing is carried out with roughly 25 vessel and gear combinations (Sathianandan et al., 2021). The principal fishing gear used in coastal fishing are trawls, gillnets, seines, bag nets, lines, and traps. Trawl fishing is one of the active fishing practices, targeting a wide range of commercially valuable species. Major targets are shrimps, cephalopods and high valued demersal fishes (Dineshbabu et al., 2014). In India, trawl fishery contributes about 52% of the total marine fish landing and around 30,486 units of trawlers are actively operated in Indian waters (CMFRI-FSI-DoF, 2020).

Marine mammals, particularly dolphins, interact most closely with fishing systems. In a recent fishing trip onboard FV Matsyakumari II, our research team documented the interaction of an adult Indian Ocean humpback dolphin, *Sousa plumbea* (Figure 1) with the trawler. The animal was spotted at a depth of 30 m, approximately 10 Nautical miles away from the shore (9.892172 N, 76.051276 E). The net was dragged for a duration of 1 hour. While hauling the net, a single animal approached the cod end and exhibited foraging behavior. The interaction lasted for 15 minutes till the hauling was completed (Figure 2).

Figure 1. Illustration of Indian Ocean Humpback Dolphin (*Sousa plumbea*)
Courtesy : Rebecca Robinson/ naturepl.com

Figure 2. Humpback dolphin interacting with trawl net codend, view from onbard RV Matsyakumari II of ICAR-CIFT

The Indian Ocean humpback dolphin (*Sousa plumbea*) prefers near-shore habitats, including estuaries. Distribution of *Sousa plumbea* extends from South Africa to Myanmar. The major threats identified for this species are incidental death due to interaction with the fishing systems and estuary habitat loss. Humpback dolphins appear to have a fairly adaptable diet, consuming a variety of fish species, and occasionally include crustaceans, squids, octopus, and cuttlefish (Barros et al., 2004). Humpback dolphins employ various feeding techniques, such as partially stranding themselves on shore while chasing fish. They are known to follow fishing systems to opportunistically feed on discarded and escaped fish (Parra & Jefferson, 2017). Jog et al. (2024) detailed the interaction of humpback dolphins and their behaviour in different fishing systems of Sindhudurg, Maharashtra, India.

Panicker et al. (2018) studied the Spatio-temporal distribution and estuary use pattern of *Sousa plumbea* in Kochi Harbor and recorded a total of 85 dolphin groups and maximum sighting was recorded in the pre-monsoon season (54) followed by post-monsoon (24) and monsoon (7). A previous study by ICAR-CIFT documented the presence of four species of dolphins, Indo-Pacific humpback dolphin, spinner dolphin, Indo-Pacific bottlenose dolphin and long-beaked common dolphin in the fishing grounds off Kochi. Among them Indo-Pacific humpback dolphin was most sighted with a total number of 1637 (Figure 3).

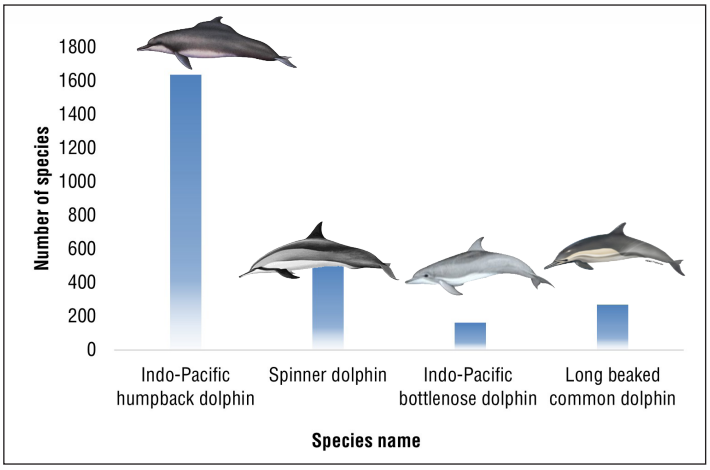
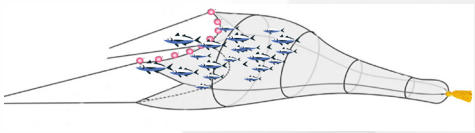


Figure 3. Species abundance of major dolphin species in the fishing grounds off Kochi Arabian Sea (Modified from Joseph et al., 2021)

There are several Indigenous mitigation measures followed in trawl fishery by the fishers to safeguard their catch and gear which include providing protection to the code end with extra cover, use of unwinded yellow rope in the cod end, use of colored lights in the trawl net, attaching yellow-colored ropes in the headrope at regular intervals etc. (Figure 4) (Prajith et al., 2024). Dolphin pingers are also used worldwide in trawl nets for the effective control of dolphin attacks. This is a globally accepted and scientifically recommended mitigation measure.

a) Protection to the code end with extra cover



b) Use of unwinded yellow rope in the cod end

Figure 4. Indigenous mitigation measure adopted in trawl nets to prevent dolphin interaction

The interaction between dolphins and trawl fishing is a complex issue that requires a collective effort from fishermen, environmental organizations, and government authorities. Finding a way to mitigate these interactions is not only crucial for the conservation of dolphins but also for the sustainability of the fishing industry and the marine ecosystem as a whole.

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Hydroxyapatite from fish waste: A candidate material for bone grafts

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Losing bone after a tooth extraction can create challenges for future dental implants and prosthetics. Keeping the shape and size of the bone and the socket where the tooth used to be is crucial for successful implant procedures. Tooth extraction itself can cause damage due to the removal of soft tissue and loss of connections in the gums, as well as changes in blood flow within the socket. Using less invasive extraction methods can help reduce this damage and prevent the socket walls from expanding. After extraction, the choice of surgical techniques and materials is key to preserving the bone structure. Although the body naturally remodels the area, this process can unfortunately reduce the width and height of the bone.

To combat bone loss, various methods have been developed to preserve the socket, including different types of bone grafts and membranes. These scaffolds help cells grow and form new tissue. While using the patient's own bone (autografts) is considered the best option, it can lead to complications at the donor site. As a result, synthetic materials like hydroxyapatite (HA) are often used because they support cell growth and bone integration. However, synthetic hydroxyapatite has its downsides, such as being slow to absorb and is costly. This has led researchers to look for more affordable natural alternatives (De Angelis et al., 2022).

Fish scales, a byproduct of sea food industry, contain hydroxyapatite, a key mineral component of bone and tooth. Recent studies have explored deriving hydroxyapatite from fish scale (FSHA) for use as a bone graft substitute (Binsi et al., 2022). FSHA has a chemical composition and structure similar to natural bone mineral, showing promising results for bone regeneration in lab and animal studies. Early research showed that FSHA supports the attachment and growth of bone cells, indicating its safety and efficacy for medical use. Despite these positive lab findings, further research is needed to evaluate FSHA in bone regeneration under clinical conditions.

This study aimed to evaluate the effectiveness of FSHA particles for preserving bone structure after tooth extraction in a rat model. FSHA was derived from rohu fish scales. The biocompatibility and bone-forming potential of FSHA were confirmed using Saos-2 cells. In vivo experiments were performed on Sprague Dawley rats, comparing the bone regeneration capacity of FSHA to a commercial bone graft material (Osseograft) over an 8-week period following graft implantation.

The results confirmed the purity of FSHA and FSHA-seeded cells and showed enhanced viability compared to commercial osseograft and untreated sockets (Thomas et al., 2024). Similarly, in rats, FSHA led to superior bone regeneration compared to osseograft and untreated sockets, with a balanced rate of graft resorption and new bone formation (Figure

1). Histological analysis showed that FSHA was effectively incorporated into new bone, with minimal defect gaps. By eight weeks, about 50%–60% of FSHA was resorbed, closely matching the rate of new bone deposition. FSHA stimulated more bone formation in the deeper parts of the socket compared to the upper areas.

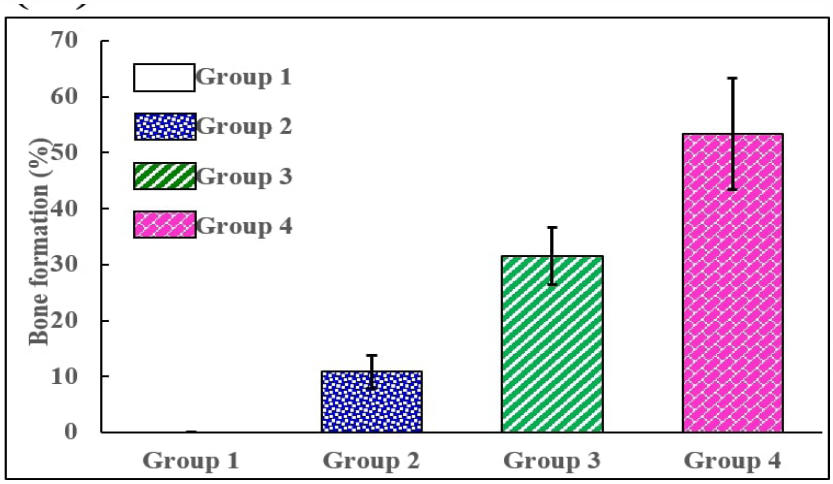

Figure 1: The percentage of new bone formation in various groups. Group 1: Non extracted tooth kept for comparison, Group 2 : Negative experiment control (without socket presevation), Group 3 : Positive control with osseograft implant and Group 4 : Group with FSHA graft

Summarising the study, FSHA is a promising material for preserving the bone structure after tooth extraction. It shows excellent compatibility with human tissues, promotes bone growth, and balances resorption and new bone formation. These findings highlight the potential of FSHA as an effective and affordable alternative to current bone graft materials used in dental procedures.

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Effect of thermal processing on production of different grades of chitosan

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Chitosan is one of the most researched biopolymers having a wide spectrum of applications. Chitosan exhibits an array of properties due to its molecular properties such as pattern of acetylation, degree of deacetylation (DDA) and molecular weight. As the interest on the functions of chitosan has grown over the time, the specificity of chitosan has gained importance, in turn the process of making particular type of chitosan. Available literature indicates that there are two type of deacetylation, homogenous and heterogenous deacetylation. The later one is more common in industrial chitosan production in which deacetylation involves strong alkali and high temperature. The present investigation explores direct thermal degradation of commercially available chitosan and also attempt was made to deacetylate chitin sourced from industry as means of producing different grades of chitosan.

High molecular weight chitosan (HMWC) was procured from SRL, India and commercial chitosan was sourced from India Seafood, Kerala. Thermal degradation of HMWC was carried out at different temperatures between 35 and 85°C. Simultaneously, the effect of autoclave processing on commercial chitosan was also investigated as influenced by two different duration (30 and 60 min). Deacetylation of chitin in different process conditions (Table 1) was carried out using sodium hydroxide. Deacetylation was carried out in autoclave, water bath (95±2°C) and in double jacketed steam kettle. Viscosity of chitosan samples produced was measured using rotational shear viscometer with appropriate spindle. Degree of deacetylation was estimated using UV spectroscopic method.

Sample	Process conditions
Batch-1	Alkali-60%, 60 min, Autoclaving, Chitin: Solvent-1:10
Batch-2	Alkali-50%, 60 min, Autoclaving, Chitin: Solvent-1:10
Batch-3	Alkali-50%, 60 min, Water bath, Chitin: Solvent-1:10
Batch-4	Alkali-55%, 60 min, Water bath, Chitin: Solvent-1:10
Batch-5	Alkali-45%, 60 min, Water bath, Chitin: Solvent-1:40
Batch-6	Alkali-50%, 60 min, Water bath, Chitin: Solvent-1:40
Batch-7	Alkali-45%, 120 min, Steam heating, Chitin: Solvent-1:40

Table 1: Details of processing conditions employed in chitosan production

HMWC in the temperature range of 65-85°C resulted in the formation of medium molecular weight chitosan (viscosity 439-310 cP) (Figure 1). Effect of temperature on the stability of chitosan in acetic acid has been assessed with reference to intrinsic viscosity. Chitosan solution prepared in acetic acid and stored at 40°C has shown almost 50% reduction in intrinsic viscosity (Harding, 2010). Higher temperature and prolonged storage period exhibited more hydrolysis of chitosan polymer chains (Nguyen et al., 2008). However, in the present investigation, the duration was kept constant and thermal degradation of chitosan in acetic acid solution was studied at different temperature. The reduction in viscosity was higher at higher temperature. The viscosity obtained in the temperature range of 65-85°C was falling in the class of medium viscosity/medium molecular weight grade chitosan. Hence, one of the methods to produce medium viscosity chitosan is a simple thermal processing of HMWC, followed by precipitation using alkali, washing to remove the salt impurities and drying.

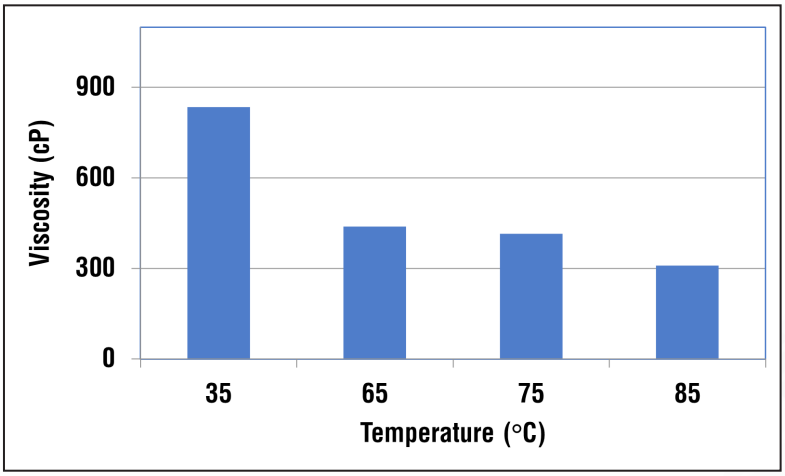

Figure 1: Changes in the viscosity due to thermal processing

Further, for producing the low molecular weight chitosan, autoclaving process was explored at two different time period, 30 and 60 min which produced chitosan with a final viscosity of 3.26 and 1.54 cP, respectively (Table 2). The study showed that from HMWC producing low molecular weight chitosan through autoclaving process needs more control with reference to time and temperature. Otherwise, it led to the formation of very low molecular weight chitosan as revealed by viscosity values. The mechanism and rate of thermal degradation of chitosan are influenced by the factors such as purity, residual moisture, molecular weight, degree of deacetylation, polydispersity, and crystallinity (Szymańska & Winnicka, 2015). A 60% reduction in molecular weight of chitosan has been reported by treating with saturated steam in the form of chitosan solution in acetic acid. The degradation has been attributed to

the scission of glycosidic bond due to higher molecular mobility (Juan et al., 2012). Obtained results indicated that autoclaving of HMWC was, one of the methods for producing very low molecular weight chitosan or chitooligosaccharides. However, autoclaving was not a suitable method to produce low molecular weight grade chitosan which exhibits the viscosity in the range of 50-200 cP.

	Control	Overnight at RT	Autoclave 30 min	Autoclave 60 min
Viscosity (cP; 60 rpm)	2910	1316	3.26	1.54
Reduction in viscosity (%)	-	54.88	99.88	99.94

Table 2: Effect of autoclaving on the viscosity of chitosan

Effect of different modes of thermal deacetylation of chitin using NaOH was attempted and the results are presented in Table 3. Based on the results obtained for viscosity under autoclaving assisted deacetylation, alkali concentration of 50% and 60% had no significant effect on DDA (slight increment from 75.50 to 77.30%), but viscosity of resulted chitosan at 60% alkali concentration was lessened by 75%. Results indicated that from same chitin, by carefully selecting the process variables, different molecular weight grade chitosan can be produced. Earlier study on chitosan production using autoclaving process found to produce the chitosan with a viscosity of more than 2000 cP and DDA of 90% at a chitin to alkali ratio of 1:15 for a deacetylation period of 30 min (No et al., 2000). However, it should be mentioned that the quality of chitosan produced under given set of process conditions was largely governed by the polymer quality of chitin.

Chitosan sample	DDA (%)	Viscosity (cP)
Batch-1	77.30	178
Batch-2	75.50	722
Batch-3	91.90	31
Batch-4	82.60	132
Batch-5	80.80	232
Batch-6	81.50	190
Batch-7	75.00	68

Table 3: DDA and Viscosity of chitosan produced by thermal processing from industrial chitin

Another three set of chitosan were produced by carrying out the deacetylation process in water bath at 95±2°C at different alkali concentrations and solid to solvent ratio. In contradiction to the observations reported at higher alkali concentration (55%), low degree of DDA (82.60%) was observed at alkali concentration of 50%, DDA of 91.90% was recorded with the corresponding viscosity values of 132 cP and 31 cP. It has been reported that higher NaOH concentration (greater than 40%) encourages degradation of amino groups of chitosan sample, which results in reporting of low DDA. However, further investigations are required

in this regard for confirmation. However, in the solid : solvent ratio of 1:40, deacetylation of chitin using 45 and 50% alkali yielded chitosan without notable change in DDA (80.80 and 81.50%) and with an observable difference in viscosity (232 and 192 cP). In another experiment, deacetylation of chitin was carried out in a jacketed kettle heated indirectly by saturated steam of vapour (120°C). The process resulted in the production of chitosan with a DDA of 75% and viscosity of 68 cP.

Overall, from the study HMWC (viscosity-722 cP), medium molecular weight chitosan (viscosity-178, 232 cP) and low molecular weight chitosan (viscosity-31, 68, 132, 190 cP) was produced from chitin by employing thermal processing. However, the degree of deacetylation varied widely from 75.50 to 91.90 % and uncontrollable.

Based on the results of the work carried out, having control over the process of producing different grade of chitosan from high molecular weight chitosan in the solution form through autoclaving is impossible. Ultimately, such processes produce chitooligosaccharides due to heat assisted acid hydrolysis. This approach is quite costly, voluminous and initial chitosan loading has the limitation on the productivity. However, such approach is useful for producing chitooligosaccharides specifically for agricultural applications like foliar spray. In the second part of the study where chitin was used to produce chitosan using different mode of thermal processing employed for heterogenous deacetylation of chitin, different grades of chitosan could be produced.

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Liquid Nitrogen (LN_2) as a chilling medium for *Etroplus suratensis* during onboard storage

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Cryogenic chilling and freezing adoption in the food industry is predominantly driven by liquid nitrogen (LN_2) over mechanical refrigeration. LN_2 as a refrigerant allows food to be chilled or frozen rapidly and uniformly, preventing the formation of large ice crystals, minimizing cellular damage, and maintaining product quality during storage and transportation (Nesvadba, 2008). In the food industry, cryogenic cooling can be achieved by two methods. Initially, a controlled amount of LN_2 will be injected directly into a refrigeration chamber using spray to maintain the chamber's temperature. This method has been adopted to preserve meat, fruits, vegetables, and various prefabricated food products (Mei et al., 2018). However, this approach has limited application due to safety and health concerns. Another method used in commercial applications is an indirect usage of LN_2 as a refrigerant wherein a heat exchanger is employed and cold air will be circulated continuously and uniformly through the refrigerated chamber (Global Cold Chain News, 2011). The usage of LN_2 as a refrigerant for chilling or freezing fish and fishery products is limited. In particular, the use of LN_2 in onboard fishing vessels to preserve the quality of aquatic resources is yet to be reported.

Figure 1. Liquid nitrogen chiller installed in the ICAR-CIFT fishing vessel

A new technology, "MATSYA" (Marine Advanced Transportation and Storage Yantra/appliance), has been developed for refrigerated fish transport in fishing vessels. This technique uses a combination of Liquid Nitrogen (LN_2) and solar energy as the hybrid source for pre-cooling and thereafter maintaining the temperature of fish during storage. The unit has a fish storage capacity of 450 kg and an LN_2 holding tank capacity of 230 liters, developed by Raja Ramanna Centre for Advanced Technology (RRCAT), Indore, and installed in ICAR-CIFT fishing vessel (Figure 1). A preliminary shore-based study using freshly caught *Etroplus suratensis* was conducted by employing a storage temperature of 4°C in the LN_2-based chilling unit installed in the fishing vessel. To evaluate the fish quality and safety, microbial and biochemical indices were monitored for 48 hrs.

Aerobic Plate Count (APC) showed an initial value of 5.67±3.54 log cfu/g, and upon storage, it dropped to 4.38±2.92 log cfu/g after 24 hrs of storage (Table 1). Further, it gradually increased to 4.49±2.41 log cfu/g after 48 hrs of storage due to the psychrophilic bacterial growth. A similar result was observed in H_2S formers, where the initial count was 3.49±2.15 log cfu/g, which dropped to 3.3±2.32 log cfu/g after 24 hrs and further slightly increased to 3.41±2.15 log cfu/g after 48 hrs of storage. The *Pseudomonas* sp. initial count was 3.29±1.84 log cfu/g and it further decreased to 3.24±2.31 log cfu/g and 2.47±2.15 log cfu/g after 24 and 48 hrs of storage respectively (Table 1). This study revealed that the LN_2-based refrigeration effectively minimized the bacterial counts and maintained the fish microbial quality within the acceptable limit of fresh fish (5×10^5 cfu g-1) (ICMSF, 1986).

Microbial analysis	**Fresh (0 hrs)**	**After 24 hrs**	**After 48 hrs**
APC (Log cfu/g)	5.67±3.54	4.38±2.92	4.49±2.41
Pseudomonas sp (Log cfu/g)	3.29±1.84	3.24±2.31	2.47±2.15
H_2S Formers (Log cfu/g)	3.49±2.15	3.3±2.32	3.41±2.15
Biochemical analysis			
TBARS	0.47 mg MDA/kg	0.25 mg MDA/kg	0.24 mg MDA/kg
TVB-N	7.78 mg/100g	6.98 mg/100g	7.67 mg/100g

*TMA and PV values were zero after 48 hrs storage

Table 1. Microbial and biochemical quality analysis of *Etroplus suratensis* stored in the LN_2-based chilling unit

TBARS value, an indicative of oxidative changes, was 0.47 mg MDA/kg, slightly decreasing after 24 hrs (0.25 mg MDA/kg) and 48 hrs (0.24 mg MDA/kg) of storage. TVB-N showed an initial value of 7.78 mg/100g and slightly decreased after 24 hrs (6.98 mg/100g) of storage. Further, it increased to 7.67 mg/100g after 48 hrs of storage in the LN_2-based

chilling unit. Overall, it was observed that the biochemical parameters of *Etroplus suratensis* were within acceptable limits, and the unit effectively maintained the biochemical quality up to 48 hrs of storage.

LN_2 based refrigeration technology can be suggested as an alternative for maintaining the quality of commercially traded fish. It could be one of the best options for fishing industries to replace traditional icing, chilling, and freezing processes in the onboard fishing vessels due to its advantages such as high efficiency, quick freezing or chilling, energy saving, environmental protection, and light volume. Further studies are required on different species as well as for extended duration for use in multi-day fishing vessels and the cost-effectiveness must be worked for commercially viable fishing operations.

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Combined curing: A novel approach towards value addition

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Drying and pickling are ancient methods of fish preservation and are considered to be economically viable options of food processing. The drying process exploits a spectrum of techniques ranging from simple inexpensive natural drying to novel hybrid drying technologies. Fish is dehydrated to reduce its water activity aiming for improved shelf life by inhibiting microbial activity as well as chemical and enzymatic reactions. Consumption of dry fish offers diverse nutritional and health benefits as it is a great source of quality protein, healthy fat and vitamin D which is known to aid in regulatory functions in the human body. In addition, it provide beneficial effects to the heart, help to maintain a healthy brain, decelerate ageing and prevent various diseases like cardiovascular diseases, osteoporosis, depression, cancer etc. (Fitri et al., 2022).

Pickles are a traditional condiment usually used as an appetizer or side dish. Through pickling, the foods are preserved in acidic brine with improved texture and flavor. Different additives are incorporated to dry fish to augment its value. Spices like turmeric, pepper and chilli are used as additives in the dry fish to repel insects in addition to improving the sensory attributes of the products (Nuwanti et al., 2016). Pickling aids in preserving dry fish using flavourful spice blends, vegetables, oil and other ingredients to brand exciting flavours and aromas. The strong-bold flavour makes the dry fish pickle unique compared to other pickles. Through pickling, the delicious savoury taste, saltiness of dry fish is combined with the tanginess of vinegar and the pungency of the spices. It is essential to diversify the market forms of value-added dry fish products to reach a wide range of customers and distant markets.

Due to increasing demand for value-added cured fish products among consumers, two different recipes were standardized for dried mackerel and dried croaker pickles. These fishes were selected considering their availability and to evaluate the suitability of lean as well as fatty fish for combined curing. The product was stored at ambient condition for six months.

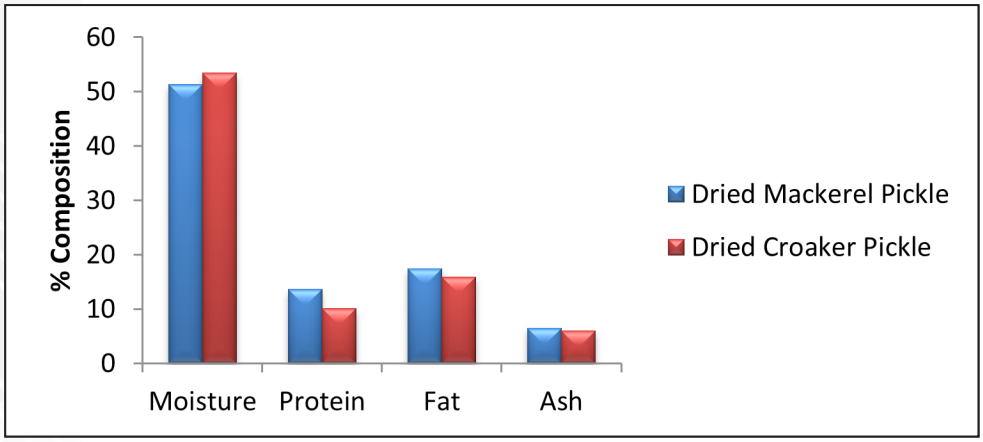

Figure 1. Proximate composition of dry fish pickles

The proximate composition of the pickles was analyzed. The moisture content varied from 51.36±0.11% to 53.41±0.89%, crude protein content varied from 10.06±0.03% to 13.59±0.49%, crude fat varied from 15.91±0.22% to 17.43±0.47% and the ash content varied from 6.02±0.47% to 6.48±0.06% within the samples. The samples were subjected to biochemical, microbial and sensory analysis. The sensory acceptance of the products were good and there was no significant difference observed in the sensory scores during the storage study. During the storage period of six months, there was a 9.7% reduction in the moisture content of pickle prepared from dried croaker, whereas, a reduction of 2.1% moisture was noticed for pickle prepared from dried mackerel. Similarly, a decrease in moisture content was also reported by Chandrashekar, Rudrasetty & Aswathnarayana (1978). Compared to the reported values of proximate composition in fish and shrimp pickles (Shiriskar, khedkar & Sudhakara, 2010; Tinku et al., 2022), the fat and ash content of dry fish pickles was comparatively higher and the protein content was found lesser. The pH of the pickle was maintained below 4.5 during the storage period in both the samples. The total volatile basic nitrogen values (TVBN) of both the samples increased up to 22.4 mg% at the end of six months, while, trimethylamine (TMA) values remained below 10 mg% for both the samples. The peroxide values (PV) increased during storage period but remained below the acceptable limit of 10-20 meq O_2 Kg^{-1}. The free fatty acid (FFA) values increased up to 2.3% oleic acid with no detection of rancidity organoleptically. Also, thiobarbituric acid (TBA) value reached to the limit of 2 mg malonaldehyde/Kg at the end of six months.

The estimation of the aerobic plate count of the samples showed a gradual decrease in the count during the storage period which might be due to the antibacterial effect of the ingredients in the pickle like spices (Chellaram, 2015) and the acidity of the product.

The absence of yeast and mould, *Escherichia coli, Staphylococcus aureus, Salmonella* spp. further assured the safety of consumption of dry fish pickles. Briefly, the pickle prepared from dried mackerel and dried croaker was sensorily well accepted and these products were shelf stable throughout the study period of six months.

Combined curing can greatly enhance the quality of dry fish especially by improving its sensorial attributes. By this hurdle technology viz. drying and pickling, the safety aspects of the product can be improved as it inhibits the growth of spoilage and pathogenic microbes. Further, the technique adopted can help in diversifying the market forms of cured products.

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Characterization of fish sauce prepared from mahi mahi fish fillet frame

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Mahi mahi (*Coryphaena hippurus*) is one of the important economic fish species in India, valued for its white meat. It has been widely utilized for fillets and fillet-based fish products in domestic and international market. During fillet production, large quantities of fish waste such as fish head, fish fin, tail, skin, central bone and viscera are generated and discarded. Solid fish waste such as head and frame from fish processing is underutilised and generally discarded. Sometimes, these wastes are utilized as fertilizer in agriculture field or used as feed for fish and livestock. However, this fillet waste is rich source of protein, lipid, enzymes and other bioactive compounds. Therefore, it is important to convert fisheries waste into high value by products. Utilisation of fish solid waste can open new scope for development and formulations of fish products due to its economic value and availability.

Fish sauce is a popular condiment used for flavouring in various Asian cuisines due to its availability, economic viability and acceptability in Asian countries. Traditional fish sauce is prepared by mixing fish with salt in a ratio 2:1 to 3:1, followed by fermentation at 35-40°C for 12–18 months or longer until fully matured (Tsai et al., 2006). Through fermentation, fish sauce attains its known brown colouration and distinct odour and taste. Recent research has explored various methods to accelerate the fermentation process and enhance production efficiency using techniques like higher temperatures, reduced salt, fish viscera or intestine, bacterial starter cultures, plant proteinases and soybean koji (Auttanak et al., 2022).

The present study was aimed to investigate the effect of fish viscera on chemical and physical changes of fish sauce during fermentation process. Cleaned Mahi mahi viscera was mixed with cold distilled water at a ratio of 1:1 (w/w) and then ground. The crude proteinase was sourced from this mixture, by filtering the ground viscera using double sheet muslin cloth. Mahi mahi fillet frame waste (head, fin, skin and frame) was used to prepared the fish sauce. To the ground frames, distilled water was added at the ratio of 1:0.3 (w/w) and digested using 10% of crude proteinase from Mahi mahi viscera for 12 hours at ambient temperature. Digested Mahi mahi frame was used as a raw material for preparation of fish sauce by mixing with 20 % (w/w) salt and was allowed to ferment at ambient temperature (Figure 1). During the fermentation, at regular intervals, the mixture was centrifuged and the liquid was collected

for further analysis. Chemical properties such as pH, total nitrogen, NaCl content and physical properties such as colour and non-enzymatic browning of fish sauce from Mahi mahi frame were analysed.

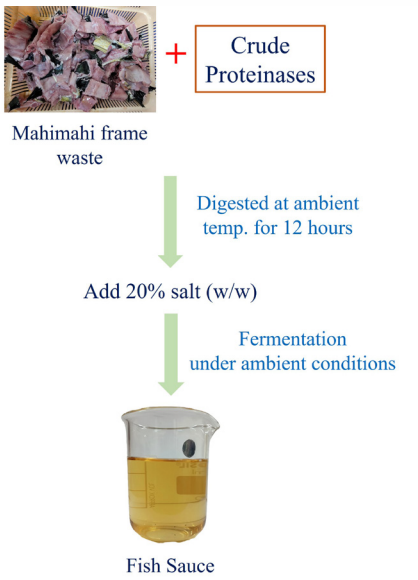

Figure 1. Flow chart of preparation of fish sauce from Mahi mahi fillet frame

NaCl content and pH of the fish sauce was in the range of 11.35% to 18.44% and 6.57 to 6.71, respectively, during the fermentation time. Salt concentration ranged from 20 to 25% in fish sauce prepared in South East Asian countries (Zhu et al., 2021), which is significantly higher than the salt content obtained in present study. The total nitrogen is an important criterion to determine the quality of fish sauce. The total nitrogen content of sample increased with increasing fermentation time (Figure 2). Chomnawang et al., (2014) reported 4.0–5.6 g/L total nitrogen content in fish sauce, which was significantly higher than the values of 1.44 to 3.12 g/L obtained in our sample during fermentation. An increase in nonenzymatic browning was observed in fish sauce during fermentation time (Figure 3). Nonenzymatic browning of fish sauce was highest at fermentation day 35, suggesting that brown pigment formed during the extended fermentation period. The nonenzymatic browning contributes to the colour of fish sauce. Non enzymatic browning in fish was evident by lower colour value as indicated by the low L*, a* and b* value (Table 1). The addition of crude proteinases from Mahi mahi viscera and salt can accelerate the liquefaction of Mahi mahi frame for fish sauce production. In conclusion, this study suggests that the Mahi mahi viscera can be used for the production of good quality fish sauce.

Fermentation days	L*	a*	b*
7	2.602	-0.604	1.898
14	2.932	-0.528	2.468
21	3.034	-0.532	2.366
28	2.948	-0.628	2.532
35	3.238	-0.65	2.81

Table 1. Colour values of fish sauce from Mahimahi frame during fermentation time

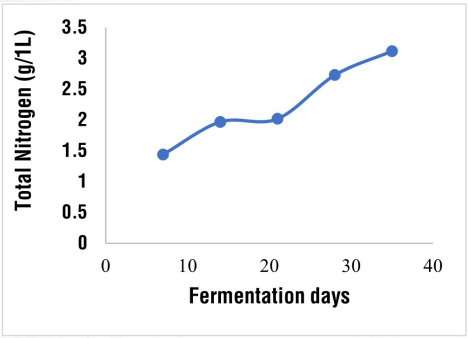

Figure 2. Total nitrogen contents of fish sauce from Mahi mahi frame during fermentation time.

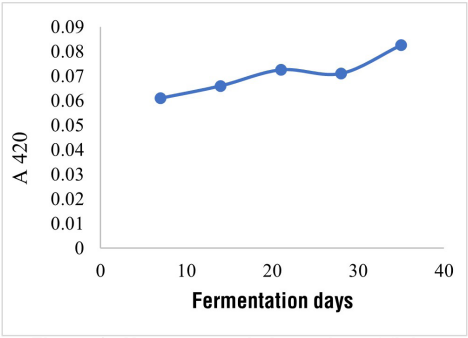

Figure 3. Non enzymatic browning of fish sause from

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Unlocking value: Heparin extraction and characterization from fish wastes

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Heparin, a widely used anticoagulant in medical practice, has traditionally been sourced from mammalian tissues, primarily porcine intestines and bovine lungs. Heparin is a polysaccharide that belongs to the glycosaminoglycan (GAG) family and is composed of repeating disaccharide units with hexuronic acid and glucosamine saccharide residues linked by 1→4 bonds. These repeating units are composed of uronic acid and glucosamine residues connected by 1→4 glycosidic bonds (Best, 1959). Heparin is made up of 75–95% of a trisulfated disaccharide repeating unit, specifically 2-O-sulfo-α-L-iduronic acid linked to 6-O-sulfo-N-sulfo-α-D-glucosamine by a 1→4 bond. The global heparin market was valued at USD 9.83 billion in 2023 and is expected to grow from USD 10.21 billion in 2024 to USD 14.45 billion by 2032, with a compound annual growth rate (CAGR) of 4.4% during the forecast period from 2024 to 2032 (Fortune Business Insights, 2024). However, the increasing demand for heparin, coupled with concerns over disease transmission and religious dietary restrictions, has prompted the exploration of alternative sources. One such promising source is fish waste, which offers a sustainable and potentially safer alternative.

Fish waste, consisting of skin, bones, scales, and viscera, is abundant and underutilized. The seafood industry generates millions of tons of waste annually, which poses environmental disposal challenges. According to the Food and Agriculture Organization (FAO) report from 2018, over 50 million tonnes of fish are discarded annually. Utilizing fish waste for heparin extraction not only addresses these environmental issues but also provides a valuable product that can significantly impact the pharmaceutical industry.

The extraction of heparin from fish waste involves several steps, beginning with the identification of suitable fish species (Nogueira et al., 2019). Certain species, such as salmon (*Salmo salar*) and tuna (*Thunnus alalunga*), have been found to contain high levels of glycosaminoglycans (GAGs), a family of molecules that includes heparin. The fish waste is first subjected to enzymatic digestion to release GAGs from the tissue matrix. This process typically involves proteolytic enzymes that break down proteins, freeing GAGs for subsequent extraction (Trindadeb et al., 2019). The heparin extracted from fish waste is then characterized to ensure its quality and efficacy. This involves determining its molecular weight, anticoagulant

activity, and structural composition. Fish-derived heparin has been found to possess similar anticoagulant properties to mammalian-derived heparin, making it a viable alternative for clinical use.

Several advantages are associated with using fish waste as a source of heparin. Firstly, it provides a sustainable and renewable source of heparin, reducing the reliance on mammalian tissues. This is particularly important in the face of increasing global demand for heparin and concerns over supply chain stability. Secondly, fish-derived heparin may offer a safer alternative, as fish are less likely to carry diseases transmissible to humans compared to mammals. This can potentially reduce the risk of disease transmission through heparin products. Thirdly, utilizing fish waste contributes to environmental sustainability by reducing the burden of waste disposal in the seafood industry.

Despite its potential, there are challenges associated with the extraction and commercialization of heparin from fish waste. Variability in heparin yield and quality across different fish species and batches can pose challenges in standardizing the production process. Additionally, regulatory approval processes for fish-derived heparin may be stringent, requiring extensive testing and validation to ensure safety and efficacy.

In this study, heparin was initially extracted in the form of GAG (Glucosaminoglycan) from Rainbow trout (*Oncorhynchus mykiss*) visceral wastes following the method of Arumugham and Shanmugam (2004) with minor modifications followed by further purification and characterization. The spectrophotometric analysis of the extracted sample, compared to a standard heparin, confirmed that the maximum absorption for the heparin standard occurred at 199.31 nm, while the extracted compound showed a maximum absorption at 201 nm.

Figure 1: Crude GAG extracted from fish viscera

Analytical Parameters	Characteristics
Physical state and morphology	Fine powder
Appearance in solution (1%)	Clear
pH	6.83 + 0.93
Color	Off white
Aqueous Solubility	Soluble
Organic Solubility	Insoluble

Table 1: Analytical Parameters of the isolated heparin

In conclusion, the extraction of heparin from fish waste represents a promising avenue for sustainable and safe anticoagulant production. By leveraging the abundant and underutilized resource of fish waste, this approach addresses environmental concerns, diversifies heparin sources, and potentially enhances the safety profile of heparin products. Continued research and development in this field can pave the way for the commercial viability of fish-derived heparin, ultimately benefiting both the pharmaceutical industry and the environment.

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Imidacloprid residue analysis and estimation of its withdrawal period in *Macrobrachium rosenbergii*

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Pesticides are extensively used chemicals in sectors such as agriculture, forestry, and the food industry. Globally, an average of 2 million tons of pesticides are used each year (De et al., 2014). India being a leading agrarian country, uses pesticides extensively for crop production (Sharma et al., 2019). Kuttanad (Figure 1) is internationally recognized for its unique agroecosystem with about 55,000 ha of paddy fields and hence called the rice bowl of Kerala.

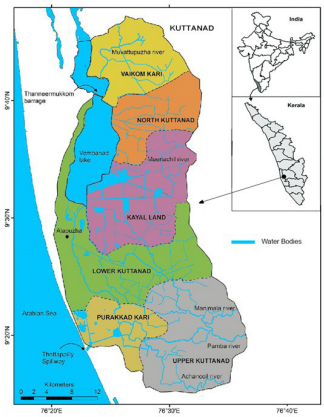

Figure 1: Map of Kuttanad

Imidacloprid is a potent, broad-spectrum, nitromethylene insecticide of the neonicotinoid family, widely used against several species of Coleoptera, Diptera and Lepidoptera in the paddy fields of Kuttanad. It is reported to contaminate surface and ground waters (Nemeth-Konda et al., 2002) in ecosystem where *Macrobrachium rosenbergii* lives and is easily transported into estuaries (Butcherine et al., 2019) where *M. rosenbergii* spawns and completes the larval phase of its life cycle (Ling, 1969).

The giant freshwater prawn, *M. rosenbergii* is a commercially important indigenous species of Kuttanad with rapid growth, large size, and high nutritive value (Kurian and Sebastian, 1976). The population of *M. rosenbergii* in the Kuttanad region is at higher risk of imidacloprid exposure via water, sediments and food sources (USEPA, 1995). Its wild stock

and culture have drastically declined in recent decades (Kurup & Harikrishnan, 2000) owing to the aquatic contamination and destruction of its habitat as mentioned by Rose et al. (2022) (Figure 2). Hence an attempt was carried out to estimate the amount of imidacloprid present in the prawns living in contaminated ecosystem and to determine the withdrawal period of imidacloprid in *M. rosenbergii*.

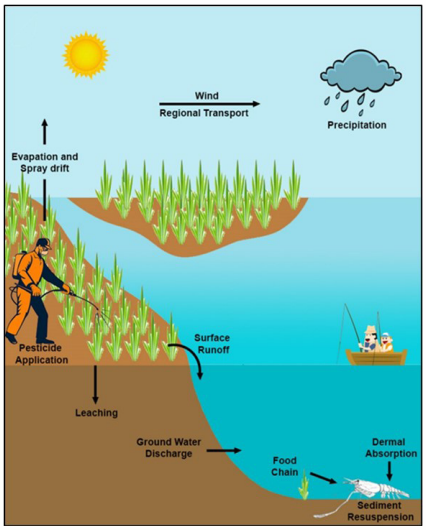

Figure 2. Imidacloprid contaminating the aquatic ecosystem (Rose et al., 2021)

A microcosm experiment was carried out in rectangular synthetic tanks set up with a Kuttanad paddy field model (Figure 3) with 40 experimental prawns. Imidacloprid (0.125l/Ha) was applied to the paddy grown in the microcosm on the first day of experiment and prawn samples were examined for the presence of imidacloprid on alternate days after the application of imidacloprid during the 90 days experimental period. The imidacloprid residues in the prawn samples were extracted with acetonitrile by the procedure described by Chatterjee et al. (2016) and analysed using LC-MS/MS. The results revealed that 0.38% of the imidacloprid applied to the paddy were accumulated in the prawns and the average concentration of imidacloprid detected in prawns was 3.04±1.5 µg/Kg. The highest concentration of imidacloprid detected was 9.29±0.7 µg/Kg, 68 h after the application of imidacloprid and its concentration decreased with time (Figure 4). The concentration dropped to about 0.28±0.2 µg/Kg after 90 days. The half-life of imidacloprid in prawns was estimated using the R-based CAKE software version 3.7. The degradation pattern of imidacloprid in prawns followed Simple First Order (SFO) reaction. The DT50 value determined turned to be 13.4 days and the χ^2 error, degrees of freedom, r^2 value and efficiency determined in prawns were 4.95, 9, 0.94 and 0.94, respectively.

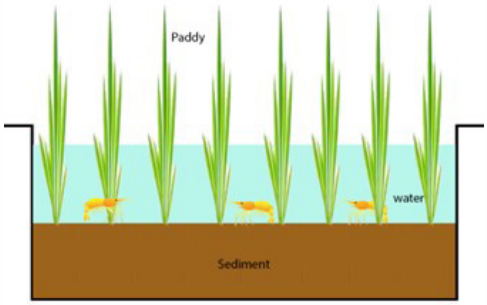

Figure 3. Schematic diagram of the microcosm experimental setup

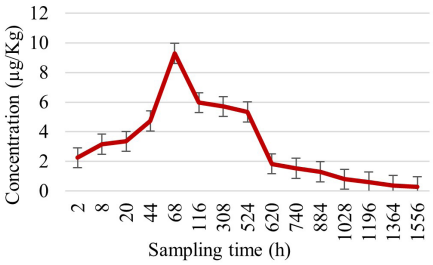

Figure 4. Concentration of imidacloprid detected in the prawns during the experimental period

Moreover, Rose & Joseph (2020) had reported that the early life stages of *M. rosenbergii* are more susceptable to imidacloprid and can reduce the larval quality and feeding rate and delay metamorphosis even at lower concentrations (Rose et al., 2023). Lake reclamation, overfishing, migratory barriers and habitat destruction are the other factors contributing to the alarming stock reduction of this species. Considering the sensitive nature of *M. rosenbergii* to environmental stress, the outcomes of the current study draw attention to the vulnerability of the organism in its habitat. Hence, the investigators of the present study suggest to reduce the imidacloprid application in the agricultural lands of Kuttanad and to promote biosafe pest management practices and to promote the sustainable aquaculture and fisheries of *M. roserbergii* in the region.

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Antimicrobial activity of carbon nanodots synthesized from sardine (*Sardinella longiceps*) fish eye

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In recent years, the development of novel antimicrobial agents has become crucial due to the rising threat of antibiotic resistance among pathogenic microorganisms. Nanotechnology offers promising avenues for the synthesis of antimicrobial agents with enhanced efficacy and reduced side effects. Carbon nanodots (CNDs) have emerged as a particularly intriguing class of nanomaterials due to their unique physicochemical properties, including high surface area, excellent biocompatibility, and tunable surface functionalities (Jiang et al., 2015).

The synthesis of CNDs from unconventional sources, such as biological waste, presents an environmentally friendly and sustainable approach. Sardine fish eye, a commonly discarded byproduct of the seafood industry, contains abundant organic compounds that can serve as precursors for CND synthesis. Moreover, the use of such waste materials aligns with the principles of green chemistry and waste valorization (Hu et al., 2014). Several studies have investigated the antimicrobial potential of CNDs synthesized from various carbon sources, including biomass and organic compounds. However, to the best of our knowledge, there is limited research focusing on the antimicrobial activity of CNDs derived from sardine fish eye. Understanding the antimicrobial efficacy of these CNDs is essential for their potential application in diverse biomedical and environmental settings.

Sardine fish eye, a byproduct of the seafood industry, represents a promising source of carbon precursors for the synthesis of CNDs. Sardines are rich in proteins and lipids, which can serve as carbon and nitrogen sources for forming carbon nanoparticles. The ocular tissues of sardine fish eye contain bioactive compounds with potential antimicrobial properties. Therefore, the synthesis of CNDs from sardine fish eye offers a sustainable approach for nanoparticle production and harnesses the starting material's inherent antimicrobial activity. In this study, an attempt was made to evaluate the antimicrobial activity of CNDs synthesized from sardine fish eye against a panel of clinically relevant microorganisms. By elucidating the antimicrobial properties of sardine fish eye-derived CNDs, this study seeks to contribute to the expanding knowledge base on sustainable nanomaterial synthesis and their applications in combating microbial infections.

Carbon nanodots (CNDs) from sardine fish eye tissue were prepared as described by Campalani et al. (2021).

Figure 1. Sardine Fish Eye

The Kirby-Bauer well diffusion method was employed to assess the antibacterial activity of the purified carbon nanodots (Bauer et al., 1966).

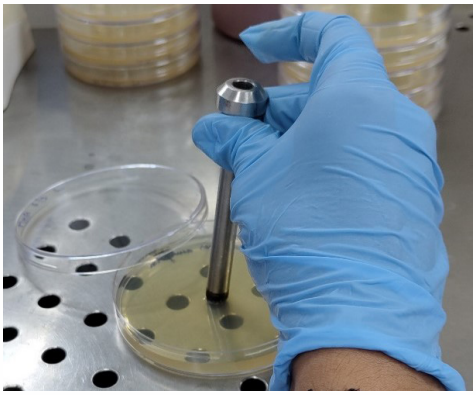

Figure 2. Kirby-Bauer well diffusion method

In this study, a total of 17 microorganisms; both Gram positive and Gram negative bacteria were employed for determination of antibacterial activity of CNDs and 93.6 μg/ml of carbon nanodot were employed for the study. The average zone of inhibition obtained for different microorganisms are given in the table 1.

Sl. No.	MICROORGANISMS	ZONE DIAMETER (mm)
1	*Bacillus subtilis* ATCC 19659	**22 mm**
2	*Escherichia coli* ATCC 25922	**24 mm**
3	*Enterococcus faecalis* ATCC 29212	**26 mm**
4	*Klebsiella pneumoniae* ATCC 27736	**23 mm**
5	*Listeria monocytogenes* ATCC 19112	**31 mm**
6	*Listeria ivanovii* ATCC 19119	**19 mm**
7	*Listeria seeligeri* ATCC 35967	**14 mm**
8	*Morganella morganii* ATCC 25829	**20 mm**
9	*Pseudomonas aeruginosa* ATCC 27853	**25 mm**
10	*Salmonella arizonae* ATCC 13314	**15 mm**
11	*Salmonella enterica diarizonae* ATCC 12325	**14 mm**
12	*Salmonella paratyphi* A ATCC 9150	**18 mm**
13	*Salmonella typhimurium* ATCC 51812	**17 mm**
14	*Shigella flexneri* ATCC 9199	**17 mm**
15	*Staphylococus aureus* ATCC 25923	**35 mm**
16	*Vibrio cholerae* MTCC 3904	**34 mm**
17	*Yersinia enterocolitica* ATCC 23715	**29 mm**

Table 1. Antimicrobial activity of CND with zone diameter by well diffusion method

Among the tested microorganisms, *S. aureus and V. cholerae* exhibited notable susceptibility to CNDs, with inhibition zones of 35 mm and 34 mm, respectively. *E. faecalis* also displayed significant susceptibility, with an inhibition zone of 26 mm. Other bacteria such as *L. monocytogenes, E. coli,* and *P. aeruginosa* also showed considerable sensitivity to CNDs ranging from 22 mm to 25 mm. The observed variation in antimicrobial activity highlights the differential susceptibility of microorganisms to sardine fish eye-derived CNDs. The significant inhibition observed against clinically relevant pathogens underscores the potential of CNDs as effective antimicrobial agents.

This study demonstrates the promising antimicrobial activity of carbon nanodots synthesized from sardine fish eye against a spectrum of pathogenic microorganisms. The findings suggest the potential of sardine fish eye-derived CNDs as effective antimicrobial agents for combating bacterial infections. Further research is warranted to optimize synthesis methods and elucidate the mechanism of action of CNDs.

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Development of fermented beverage 'Kombucha' from brown seaweed

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The growing recognition of the impressive health advantages offered by seaweed-based food products is gaining importance worldwide. However, the odour and flavour of seaweed-based food products have limitations in their appeal in geographical areas were seaweed is not part of the diet. This non acceptance can be overcome by fermentation of seaweeds. Fermentation also improves the sensory appeal, shelf life and nutritional quality of products (Allahgholi et al., 2023). Being rich in polysaccharides, seaweeds are potent substrate for fermentation. Microbial breakdown of seaweed during fermentation releases many intracellular compounds and upon biotransformation, increase their bioavailability (Reboleira, et al., 2021). Due to their ease of accessibility, brown seaweeds are explored in the field of food industries and research. Brown seaweeds are rich in polysaccharides like laminarin, fucoidan, and alginate, as well as phenolic compounds, pigments, and other bioactive substances, all of which contribute to positive effects on public health. A symbiotic consortium of bacteria and yeast (SCOBY) can be used to ferment seaweed. Conventionally used substrata for SCOBY fermentation was tea, and the fermented beverage is known as 'kombucha'. In this process, yeast breaks down complex sugars into simpler compounds like fructose, glucose etc. The bacteria then use the simpler sugar glucose to generate gluconic acid and small quantity of ethanol, leading to the production of acetic acid and a subsequent decrease in pH (Aung & Eun, 2022).

In this study, instead of tea, brown seaweed *Turbinaria conoides* (J. Agardh) Kuzing was used as fermentation substrate using SCOBY to develop kombucha. The fresh brown seaweed was collected from the Mandapam region, Tamil Nadu and brought to the laboratory where the seaweed was washed, dried and pulverized hygienically. The seaweed powder was boiled in water at 100°C for 30 min. The extract was then fermented for 15 days at 25°C under controlled conditions using SCOBY. The 'Kombucha' was analyzed for lactic acid bacteria (LAB) count, yeast count, and antioxidant capacity. LAB count and yeast count were 8.3×10^4 and <10 cfu/g, respectively. The fermented brown seaweed showed promising antioxidant activity compared to unfermented seaweed powder. In contrast to tea kombucha, seaweed kombucha exhibited higher levels of total antioxidant activity, total phenolic content, and flavonoids. The fusion of prebiotic effects from fermented food and the nutraceutical potential of seaweeds in the production of brown seaweed kombucha could present a significant and novel entry into the markets for seaweed-based functional foods and nutraceuticals.

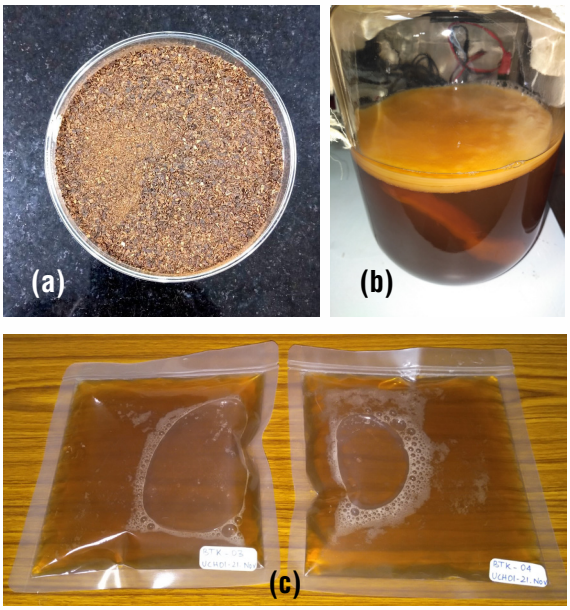

Figure 1. (a) Dried *T. conoides* powder (b) Kombucha with SCOBY* and (c) Seaweed Kombucha
***SCOBY- Symbiotic culture of bacteria and yeast**

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Ready reckoner for selection of antibiotic resistance genes (ARGs) for screening phenotypically resistant bacterial pathogens

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Antibiotic Resistance Genes (ARGs) are genes present in bacteria which enable them to evade the detrimental effects of the antibiotics. ARGs are actively involved in the antibiotic resistance mechanisms of bacteria. While, ARGs are specific to a particular antibiotic, multiple ARGs may confer resistance to single antibiotic. Notably, a single bacterium can carry several types of ARGs, providing resistance against different classes of antibiotics. Molecular techniques such as qualitative PCR assays (Simplex PCR, Multiplex PCR) or quantitative PCR assays (Real Time PCR) are used to detect ARGs in bacteria. Genome sequencing viz., WGS, metagenome analysis can also reveal the presence of ARGs (Preena et al., 2020).

Implications of spread of ARGs:

- The spread of ARGs from AMR bacteria in food producing animals to human bacterial pathogens and vice versa poses serious problems to human and animal health.
- The entry of AMR bacteria or bacteria carrying ARGs into the aquatic food production system can occur through contaminated water, contaminated feed and feed supplements, unhygienic personnel, animal manure, unclean food contact surfaces, etc.
- The transfer of ARGs primarily occurs through Horizontal Gene Transfer routes such as transformation (uptake of free DNA by a competent bacterial cell), transduction (mobilization of bacterial DNA from one bacterial cell to another by a bacteriophage) or conjugation (mobilization of DNA from a donor bacterium to a recipient bacterium requiring physical contact and conjugative machinery).

ANTIBIOTICS / Target site	Cell wall synthesis			Cell membrane	Protein Synthesis 30S Ribosome		Protein Synthesis 50S Ribosome			DNA synthesis	RNA synthesis	Metabolic Pathway inhibitors
Mechanism of action ↓	Penicillin	Cephalosporin	Penems / monobactams	Polymixin Colistin Lipopeptide Daptomycin	Aminoglycosides	Tetracyclines	Macrolides	Lincosamide	Chloramphenicol	Quinolones	Rifampin/ Rifamycin	Sulfonamides
Enzymes Hydrolysis	Beta lactamases**** Class A, B, C, D					*tetX, tet47 to tet56*	*Mph Vat*					
Antibiotic Modifying Enzymes					AAC, ANT, APH, AAD				catI to catIV			
Target site Mutation							Methyl transferase *ermB, ermA ermC, ermF*	Methyl transferase cfr	Methyl transferase cfr	DNA gyrase *gyrA-gyrB* Topoisomerase *parC-parE*	RNA polymerase	Dihydrofolate reductase *dhfr, sul*
Target modification	*mecA vanA*			*mcr-I mgrB*		*tetM, tetO, tetS, tetT, tetW, tetW(P), tet32, tet36, otrA*				*qnr*		
Efflux Pump						*tetA, tetB, tetC, tetD, tetE, tetF, tetG, tetH, tetJ, tet K*	*mef, cml, flo*			*qepA*		

Table.1. Ready Reckoner for ARG selection

****** Beta lactam classes.** • AmpC, MIR-1, P99, CMY-2, FOX-1 ACT-1: Cephalosporins • GC1, CMY-37: ceftazidime • PC1 gene: Benzylpenicillin. • SHV-1, TEM-1, TEM-2: benzylpenicillin and early cephalosporins. • SHV-2, TEM-3, PER-1, CTX-M-15, VEB-1: oxyimino β-lactams, i.e., extended spectrum cephalosporins, monobactams (cefotaxime, ceftazidime, ceftriaxone, cefepime, aztreonam).	• TEM-30, SHV-10: cause resistance to clavulanic acid, sulbactam, and tazobactam. • TEM-50: oxyimino β-lactams combined clavulanic acid, sulbactam, and tazobactam, i.e., Extended-spectrum cephalosporins monobactams. • PSE-1, CARB-3: Carbenicillin. • RTG-4: carbenicillin, cefepime, and cefpirome.	• OXA-1, OXA-10: cloxacillin or oxacillin; • OXA-11, OXA-15: cloxacillin or oxacillin and oxyimino β-lactams; • OXA-23, OXA-48: cloxacillin or oxacillin and carbapenems; • CepA: cephalosporins but this activity is inhibited by the addition of clavulanic acid but not aztreonam;	• KPC-2, IMI-1, SME-1: carbapenems, oxyimino b-lactams, cephamycins; • IMP-1, VIM-1, CcrA, IND-1 genes cause broad-spectrum hydrolysis including carbapenems but not monobactams; • L1, FEZ-1, GOB- 1, CphA, Sfh-1, CAU-1: cause preferential hydrolysis of carbapenems.

There is an urgent need to address the risks associated with the development, selection and dissemination of foodborne resistant microorganisms and resistance determinants (ARGs) along the aquatic food production-supply chain.

A ready reckoner on ARGs is necessary not only understanding the role of different ARGs but also for aiding in the selection of ARGs to be screened in bacteria exhibiting phenotypic resistance to antibiotics. In this context, a ready reckoner has been developed (Table.1) to guide researchers in selecting ARGs for screening bacteria phenotypically resistant to different class of antibiotics. The ready reckoner is prepared against most commonly used antibiotic (Murugadas et al., 2019; Vaiyapuri et al., 2023; Mothadaka et al., 2023). The ready reckoner on ARGs can be updated with identification of new ARGs against an antibiotic by any bacteria.

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Economic constraints trigger local adaptations in fishing: The case of '*Ponthu Vallam*' in Arthunkal, Kerala

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Local adaptations often occur as a creative response to existing social, economic and environmental constraints (Taalbi, 2017). Socio-ecological systems are increasingly being focused in the context of understanding innovations systems and adaptations (Melnykovych et al., 2018). "*Ponthu vallam*" is a type of traditional fishing vessel constructed primarily from thermocol (polystyrene) (Gopal et al., 2018). Emergence of *ponthu vallam* use among traditional and artisanal fishers of Arthungal fishing harbour is such an example where local adaptations are widespread due to the perceived relative advantages in the context of their economic constraints.

Arthunkal is a traditional fishing village located in Alappuzha district of Kerala, India. *Ponthu Vallam*, originally designed and used to transport fish, supplies, and crew to and from parent fishing vessel, allowing fishing vessel to stay out at sea for a long period. Due to their simple design and construction, these vessels were often seen as temporary or supplementary. However, over the years, the role of the *ponthu vallam* in fishing has expanded dramatically. Driven by rising cost of fishing, fishers have increasingly turned to *ponthu vallam* for shore-seine fishing. Despite lacking formal legal and technical permissions, *ponthu vallam* has become widespread among small-scale fishers. Today, *ponthu vallam* is a common sight at Arthunkal, where about 100 units are employed, and plays a crucial role in the daily livelihoods of small-scale fishers. In this context, this study examines the features, socio-economic drivers and the economic returns of *ponthu vallam*.

'*Ponthu*', a flat-bottomed rectangular shape, typically thermocol block wrapped in protective mesh and supported by a wooden or plastic pipe frame, is lightweight and buoyant, making it easy to handle and useful for shallow water or near shore fishing. The encased mesh is usually made of nylon or other durable synthetic materials. This covering protects the thermocol from damages. The frame supports the thermocol blocks so that the *ponthu vallam* maintains its form in the water. The top of the vessel is often covered with a waterproof fabric or tarpaulin, providing a surface for the fisher(s)and their equipment. Due to its lightweight construction, it requires less power to operate, whether rowed manually

or powered by a small engine. *Ponthu* are small, 6-meter length and 2-meter width, using 2 to 10 hp motor, with a crew of 1 or 2 (maximum) fishers. A compact, portable model of engine suitable for thermocol behaviour is used. Gillnets are the primary gear used in the vessel. *Ponthu* does not have a specific season as it covers only a short distance. Generally, June to August is considered off-season due to heavy winds and rain. The introduction of the *ponthu vallam* has brought some economic advantages to the fishing communities. Its cost-effective construction, low maintenance requirements easy maneuverability, and high probability of realising at least some positive net returns drives its adoption and popularity.

Ponthu vallam can be constructed at low capital investment and need only a limited number of fishers (1-2) for its operations. The materials needed to construct a *ponthu vallam*, such as thermocol, protective mesh, and plastic pipes, are less expensive than traditional boat-building materials like wood or fiberglass. The average capital investment for a *ponthu* is approximately Rs 75,000 to Rs 1,00,000, which increases to 1,25,000 if an engine is fitted. The materials are readily available in local markets. This reduces transportation costs. This cost reduction in materials translates to a lower overall cost for constructing the *ponthu vallam*, making it accessible to small-scale fishers with limited financial resources. The average life of a *ponthu* is about three years, and repairs and maintenance are low. In the event of damage, fishers can quickly patch or replace the damaged sections without requiring specialized skills or expensive materials. This ensures minimal downtime and keeps maintenance costs low.

Fishers felt that the primary economic benefit stems from its operational efficiency. Unlike traditional fishing units that incur recurring expenses such as labor, fuel, and maintenance, the *ponthu vallam* operates with minimal operational costs. This cost-effective nature of the *ponthu vallam* ensures at least a minimum net return for the fishers. In Arthunkal, most of the *ponthu* units are engine-free; with paddles and poles used for manoeuvring and guiding the net during deployment and retrieval. Without high operational expenses, the fishers can achieve better financial stability and a reduced variability in income flow. Some fishers mention that during the off-season from December to February, *pothu vallam* turns out to be the major source of livelihood. Also, there is no need for many labourer(s), and mostly the owner(s) function as the primary worker, therby cutting labour costs.

Fishing units	Unit effort (hrs/day)	Value of fish catch (Rs) *	CPUE (Catch per unit effort) (Rs. per manhour of trip time)	No of fishers	Average returns per person per hour (Rs.)
Ponthu vallam	5.5	1200	218	1-2	145
Fiber vallam	27.5	26624	968	4-5	215

Table 1 Comparative analysis of Catch Per Unit Effort of fishing units

Source: Primary survey done at Arthunkal from 01/07/2023 to 30/09/2023 collecting data from every fishing trip undertaken by 3 fishing units of ponthu vallam
*Note: *Catch amount is the divisible earnings of fish caught*

The comparative analysis of Catch Per Unit Effort (CPUE) between different fishing units, as illustrated in Table 1, reveals notable differences in efficiency and operational demands. The fiber vallam exhibits a higher CPUE, delivering greater catch value per hour of effort compared to the *ponthu vallam*. However, this increased efficiency comes with the requirement of significantly more time and effort per trip. In contrast, the ponthu vallam, despite having a lower CPUE, offers several advantages. It incurs lower overall costs and requires shorter trip durations. During peak seasons, the *ponthu vallam* can undertake up to two trips per day, enhancing its efficiency and productivity relative to other smaller traditional fishing units. Additionally, it maximizes the use of labour, reducing opportunity costs. The transaction cost for mobilizing fish workers to operate the *ponthu vallam* is lower than that for the fiber vallam. This reduction in initial and operational costs makes the *ponthu vallam* an economically attractive choice, ensuring a steady and reliable income for fishers with minimum costs. However, it is important to note that the sea safety of the *ponthu vallam* is not well established, posing potential risks, especially during rough sea conditions. It is not recommended as a vessel. The experts in the domain have called for halting the operation of the *ponthu vallam* through regulations.

Figure 1: Ponthu vallam at arthunkal landing centre. Source: Image by authors

The flammability of thermocol used for buoyancy or insulation, increases the risk of fire accidents, endangering the fishers and the marine environment. Authorities are cautious about granting permissions without stringent safety measures in place. This situation underscores the need for alternative materials or improved safety standards to mitigate risks. Balancing conventional practices with modern safety and environmental standards is critical to safeguarding the marine ecosystem while ensuring the safety of fishers who depend on *ponthu* and coastal communities.

The *ponthu vallam* represents a significant local adaptation as a response to the escalating cost of fishing, probability of negative net returns in fishing, economic independence and avoiding transaction cost of organizing fishers. Its adoption underscores the importance of balancing traditional practices with modern safety and environmental standards. However, venturing into the sea with the *ponthu vallam* is a risky proposition, as its seaworthiness is not established, and is not a "fishing vessel" in that sense, but remains a local adaptation to economic constraints faced by artisanal fishers. It shows that there is perceived demand for less capital and less labour-intensive fishing vessels that yield a positive net return with low-income risk, catering to the need of the small-scale fishers operating in the coastal waters.

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