

# Aqua International

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June 2026

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## Inside ...

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Sit together and resolve issues. Industry is getting organised and growing; Avoid conflicts; Ensure that farmers get Profitable price to his produce; Govt should take further initiatives to keep things in order in Aqua

White Feces Syndrome: Latest understanding and preventive measures

Optimizing Protein Levels in Shrimp Feed: Evidence from Multi-Pond Commercial Trials in Thailand



Artificial Intelligence in Seafood Processing: Transforming Freshness Detection, Quality Grading, and Automation for Sustainable Aquaculture

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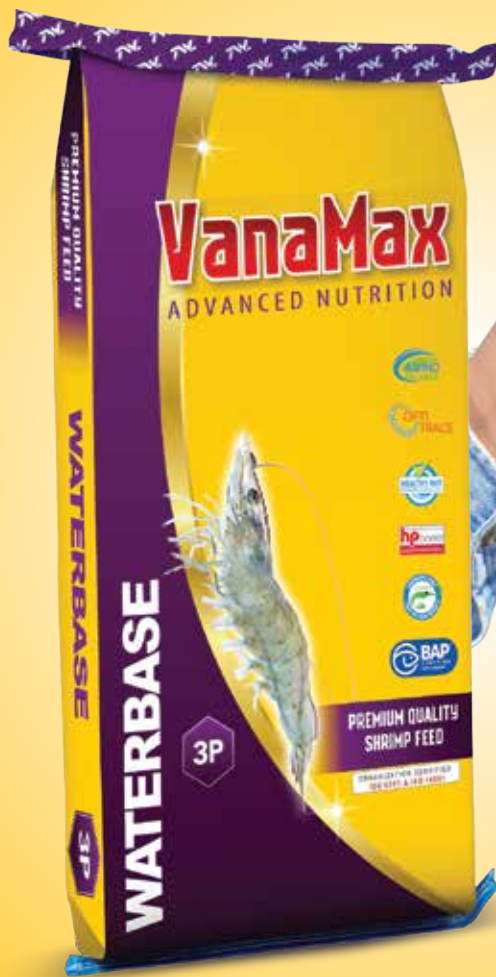
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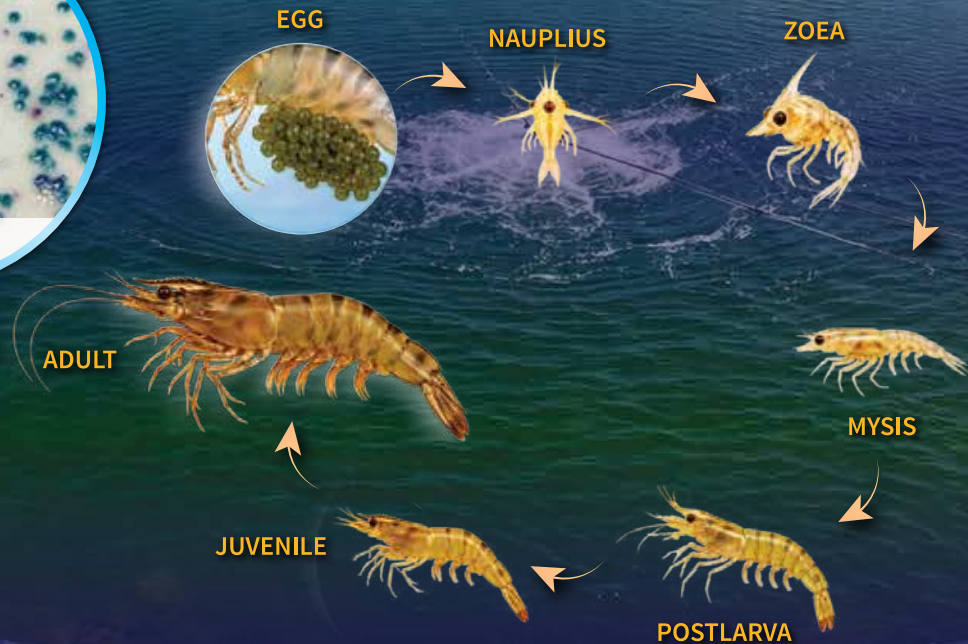


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- Editor



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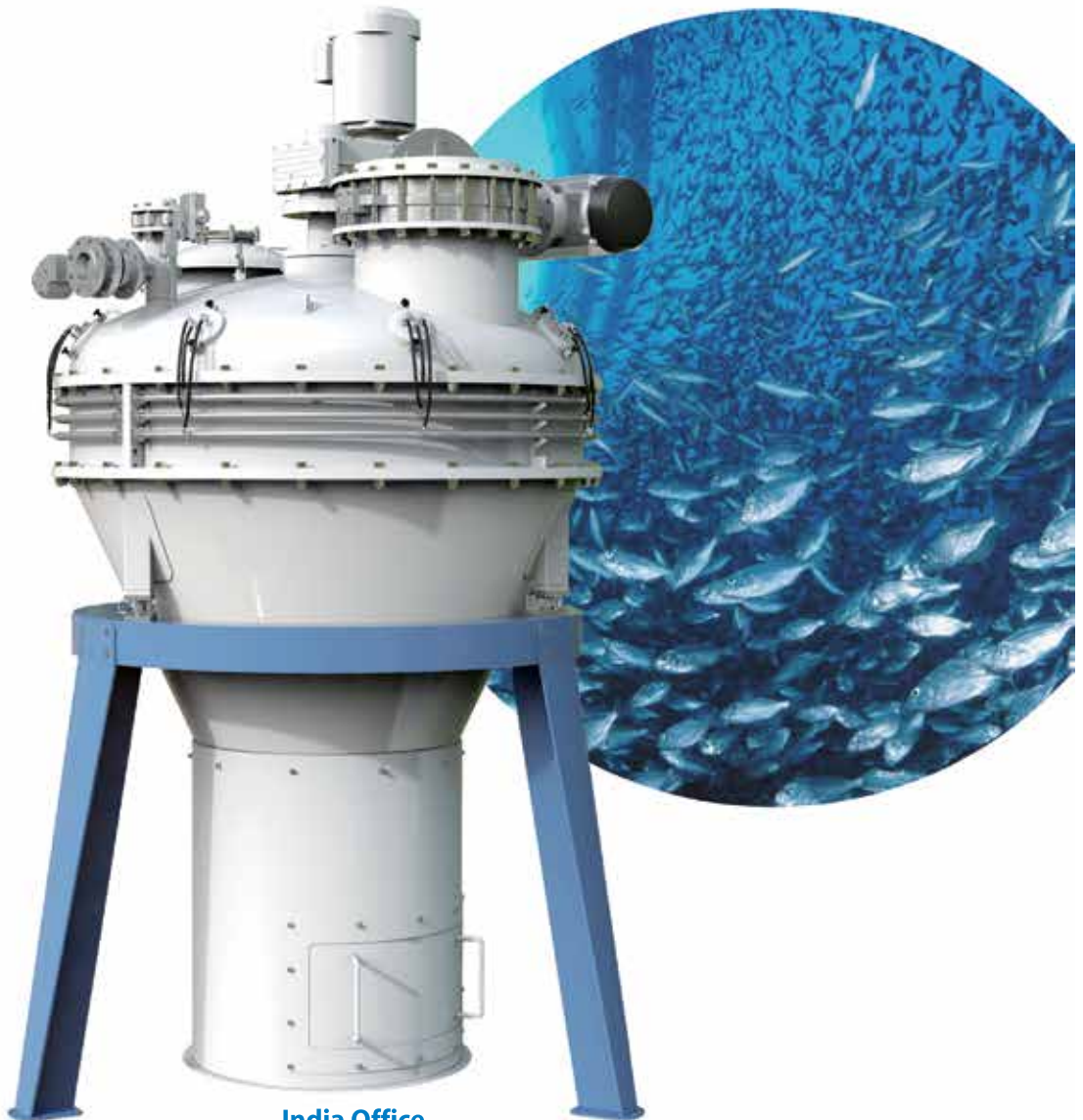
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## Sit together and resolve Issues. Industry is getting organised and growing; Avoid conflicts; Ensure that farmers get Profitable price to his produce; Govt should take further initiatives to keep things in order in Aqua

Protein is one of the most expensive components in shrimp feed, yet it is often used at levels higher than what shrimp actually require. Many farmers believe that higher protein diets will always result in better growth and higher production. But is this really true under commercial farming conditions ?



Dear Readers,

The June 2026 issue of Aqua International is in your hands. In the news section, you may find news about....

### Aquaculture farmers in Andhra Pradesh

are staging widespread protests against feed price hike by shrimp feed manufacturing companies and low raw material prices for the harvested shrimps. They are also asking for quality seed regularly. Feed companies are saying that due to West Asia war the prices of raw material used in feed have gone up abnormally causing feed price hike. The farmers are also asking the Andhra Pradesh government to bring down electricity charges to Rs 1.50 per unit.

The Indian aquaculture sector is rapidly transforming from a traditional, fragmented livelihood into a highly structured, tech-driven industry. The sector is getting organised and growing. Feed, shrimp seed producing and shrimp processing companies have started using modernization, advanced technology and practices to produce quality products. At this stage the stakeholders like the farmers and the above mentioned segments companies should not allow conflicts which will lead to gap among them. All of them should sit together and resolve issues amicably. Looking at the situation, the Andhra Pradesh Chief Minister Mr N. Chandra Babu Naidu has rightly written to the Union Minister Mr Piyush Goel for urgent policy intervention to stabilize shrimp feed raw material prices and protect India's aquaculture challenges. The A.P. Govt. should take further initiative to bring farmers, feed millers and the processors-cum-exporters together and resolve the issues, and also ensure that they all work together and grow. Ensure that farmers get profitable price to his produce.

**The farmers' technology of production** of stockable-sized seeds (post-larvae; PL) of giant freshwater prawn *Macrobrachium rosenbergii* or Scampi both in normal rural brackishwater ponds and *Litopenaeus vannamei* culture ponds exclusively in pre-monsoon months during March to May and early June, and its sale to grow-out giant prawn farmers is an established and successfully-running sector in Purba Medinipur, West Bengal. Success in grow-out *M. rosenbergii* farming, its wider adoption, extension and production in increased amounts depends upon availability of good quality PL and further more juveniles in sufficient numbers. The cost-efficient *M. rosenbergii* PL production in confined earthen pond system (800 - 2080 sq mtr area) and controlled condition is given more preference and dependence as source of stockable-sized seeds over the practice of PL capture from rivers of this district. Healthy and ripe berried Scampi females 50 - 125 gms in size carry fertilized eggs of separate stages of development (either orange, yellow and slate grey coloured, denoting less-advanced and advanced stages of embryo development within eggs) in its brood chamber on ventral side of abdomen.

**Aqua farmers worried over manufacturers' attempt to increase shrimp feed prices** Amid rising production costs, shrimp feed manufacturing companies have proposed to increase the prices again. Aqua farmers across Andhra Pradesh State have requested Chief Minister N. Chandrababu Naidu, who is also Chairman of the Andhra Pradesh State Aquaculture Development Authority (APSADA), to intervene and stop the move to increase the price. According to the sources, the manufacturers have decided to increase the prices by Rs 10 per kg on Vannamei shrimp feed and Rs 12 per kg for tiger shrimp feed. This follows rise in prices of fish meal, fish oil, minerals, binders, soybean and other raw materials used in the manufacture of the feed during the three-month period from January

*Contd on next page*



### Our Mission

*Aqua International* will strive to be the reliable source of information to aquaculture industry in India.

**AI** will give its opinion and suggest the industry what is needed in the interest of the stakeholders of the industry.

**AI** will strive to be The Forum to the Stakeholders of the industry for development and self-regulation.

**AI** will recognize the efforts and contribution of individuals, institutions and organizations for the development of aquaculture industry in the country through annual Awards presentation.

**AI** will strive to maintain quality and standards at all times.

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26 to April 26. The manufacturers have written a letter to the AP Fisheries Commissioner and APSADA to give permission for the proposed price rise. However, the aqua farmers are opposing the move as the prices have already been increased by ₪4 per kg in February 2026, citing hike in the production cost. Duggineni Gopinath, President of Prakasam District Shrimp Farmers' Association, says, The shrimp feed manufacturers have become a syndicate and are preparing to increase the feed prices again to burden aqua farmers. The Chief Minister should reject the proposal and help aqua farmers.

**White Feces Syndrome: Latest understanding and preventive measures.** Firstly described around 2010, White Feces Syndrome is an important disease for shrimp farming in Asian countries that can cause severe mortalities and economic losses. This disease is a complex syndrome whose occurrence remains unclear. The factor triggering WFS is yet unknown and this might not be the result of one single agent. Description, aetiology, and preventive measures: Techna's experts give an update. White Feces Syndrome: a syndrome that causes mortality and reduce performances. The White Feces Syndrome refers to the presence of floating white fecal strings in ponds. It can be observed in both farm-reared Black tiger shrimp (*Penaeus monodon*) and Pacific white shrimp (*Litopenaeus vannamei*). The syndrome causes several issues, including high mortality, growth retardation, size heterogeneity, and an elevated feed conversion ratio. Survival is generally reduced by 20 to 30% (Tamilarasu et al., 2020) and cumulative mortalities can be as high as 50% in the summer period (Hou et al., 2018).

In the Articles section, **Fish as a Superfood: Nutrition and Health Benefits for All Ages** authored by Arun Konduri, Divya Banothu, Tao Kara, Raveendar Banothu, Shyam Prasad. M, Narra Mohana Swapna discussed that Aquatic animal foods provide highly digestible protein with lower caloric density and higher omega-3 long-chain polyunsaturated fatty acids (n-3 LC PUFA) compared to terrestrial animal sources. Rich source of high-quality protein, essential amino acids, vitamins A and D, B-complex vitamins, and vital minerals such as iodine, selenium, and zinc. Fish and fish oil are excellent sources of omega-3 fatty acids, particularly EPA and DHA, especially abundant in fatty fish species. Fish-derived proteins and bioactive peptides exhibit ACE-inhibitory, immunomodulatory, antioxidant, antimicrobial, and anticoagulant properties. Regular consumption supports neurodevelopment, cardiovascular health, immune function, and overall physical and cognitive performance across all age groups. Contributes to nutritional security and strengthens public health through increased dietary inclusion of fish. According to FAO (2024), global apparent consumption of aquatic animal foods was estimated at 165 million tonnes in 2022, corresponding to an average of 20.7 kg per capita. This steady rise in fish consumption has significantly shaped dietary patterns and contributed to improved public health worldwide. These nutrients are highly bioavailable, contributing significantly to human growth, development, and overall health. Distinct from many other animal protein sources, fish is the primary dietary source of long-chain omega-3 polyunsaturated fatty acids, namely eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

Another article titled, **Optimizing Protein Levels in Shrimp Feed: Evidence from Multi-Pond Commercial Trials in Thailand** authored by Dr Lumpun Poolsawat, Dr Natthinee Munkongwongsiri and Dr Craig L. Browdy said that Protein is one

of the most expensive components in shrimp feed, yet it is often used at levels higher than what shrimp actually require. Many farmers believe that higher protein diets will always result in better growth and higher production. But is this really true under commercial farming conditions? A recent multi-pond evaluation conducted in Thailand provides new insights that challenge this long-standing assumption. Rethinking protein in shrimp diets: For many years, shrimp farmers have relied on high-protein diets—typically 38–45% crude protein (CP)—to support growth and production. This approach is based on the belief that higher protein levels directly translate into better performance. However, rising feed costs and increasing pressure to improve sustainability are challenging this assumption. The key question is no longer how much protein can be fed, but how much is actually required to achieve optimal results. Evaluating feeding strategies under commercial conditions To better understand the impact of dietary protein levels, three feeding strategies were evaluated across 76 commercial ponds in Thailand during 2025–2026: High protein (HP): 38% CP throughout the culture cycle; Low protein (LP): 35% CP throughout the cycle; Step-down strategy (HP+LP): 38% CP during early stages (DOC 1–30), followed by 35% CP until harvest.

Another article titled, **Artificial Intelligence in Seafood Processing: Transforming Freshness Detection, Quality Grading, and Automation for Sustainable Aquaculture** authored by Madhan. M says that AI-based fish freshness detection achieving up to 100% classification accuracy. Deep learning architectures such as FishNET-S for automated grading. Precision cutting and species classification using machine vision (98–99.7% accuracy). Smart packaging, IoT monitoring, blockchain traceability, and Industry 4.0 integration. Real-time pH sensor and machine learning applications for seafood quality assessment. Practical relevance for India and small-scale seafood processing sectors. Includes scientific figures, workflow illustrations, recent citations (2023–2025), and industrial applications. Seafood processing faces persistent challenges including rapid spoilage, subjective quality assessment, labour-intensive operations, and significant post-harvest losses. Artificial Intelligence and machine learning are emerging as powerful solutions, enabling non-destructive, rapid, and accurate evaluation of freshness while automating classification and cutting processes. This review synthesises recent advancements (2023–2025) in AI applications for seafood, covering deep learning models for freshness detection (achieving up to 100% accuracy), novel architectures like FishNET-S for quality grading, machine vision systems for species classification and precision cutting (98–99.7% accuracy), and sensor-ML integration for real-time pH monitoring. Industry 4.0 technologies, including IoT, robotics, and blockchain, further enhance traceability and sustainability.

Readers are invited to send their views and comments on the news, special feature and articles published in the magazine which would be published under "Readers Column". Time to time, we shall try to update you on various aspects of Aquaculture sector. Keep reading the magazine Aqua International regularly and update yourself. Wish you all fruitful results in your efforts.

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## Macrobrachium rosenbergii seed production in Litopenaeus vannamei ponds



*Berried females of Scampi produced in grow-out pond*

The farmers' technology of production of stockable-sized seeds (post-larvae; PL) of giant freshwater prawn *Macrobrachium rosenbergii* or Scampi both in normal rural brackishwater ponds and *Litopenaeus vannamei* culture ponds exclusively in pre-monsoon months during March to May and early June and its sale to grow-out giant prawn farmers is an established and successfully-running sector in Purba Medinipur, West Bengal. Success in grow-out *M. rosenbergii* farming, its wider adoption, extension and production in increased amounts depends upon availability

of good quality PL and furthermore juveniles in sufficient numbers. The cost-efficient *M. rosenbergii* PL production in confined earthen pond system (800-2080 sq.mt area) and controlled condition is given more preference and dependence as source of stockable-sized seeds over the practice of PL capture from rivers of this district

Healthy and ripe berried Scampi females 50-125gm in size carry fertilized eggs of separate stages of development (either orange, yellow and slate grey coloured, denoting less-advanced and advanced stages of embryo development within eggs) in its brood chamber on ventral side of abdomen. These are collected from Scampi grow-out monoculture ponds of farmers – adult ones of both male and female left unharvested further reared to attain maturity. A 100gm female may produce 50000nos of larvae.

In Scampi, gonadal maturation, mating and egg fertilization are completed in freshwater condition. Orange coloured

egg mass of berried mother prawns indicates that these are recently laid (newly-spawned eggs). Colour becomes slate grey just before hatching time. As eggs undergo embryonic development in mother's brood pouch, their colour gradually changes from orange to yellow and then to deep grey. It is the time for transferring those to brackishwater ponds; hatching of eggs and larval metamorphosis occurs in such ponds. First larval stage (FLS; poppy seeds in size) is observed within next 2-3 days of stocking of those that carry blackish-grey eggs. *Litopenaeus vannamei* culture ponds having 6-14ppt salinity level are used for Scampi larvae and PL production ponds till end of summer and onset of monsoon. Once salinity level drops due to rainfall in monsoon months, Scampi PL production will not be possible.

PL (12-25mm) are produced and harvested from ponds within a period of 15-16 days of stocking of mothers carrying grey-deep grey coloured eggs; it takes more time for those with orange-yellow egg mass. PL are sold to grow-out Scampi farmers in North 24 Parganas district and in some places in Bangladesh in oxygenated packets, fetches a very good price. Ponds are aerated everyday in early morning, forenoon and evening – continued for two hours in each time until formation of PL. Application of probiotics



*PL 5-6 days old*

bacteria, Benzalkonium chloride, Mineral-mix, lime, Zeolite, Dolomite, organic juice are applied by farmers routinely as recommended dosage to get maximum production and survivability of Scampi PL. This practice has proved to be a reliable source of income and remunerative for farmers. News communicator Subrato Ghosh observed that Scampi PL production in brackishwater ponds is carried out in different villages of Contai-1 (near to Government Fish Technological Station, Junput and others), Contai-2 (Deshapran) and Contai-3 Blocks of Purba Medinipur district by some small- to medium-scale *L. vannamei* farmers young in age. After Scampi PL harvest and sale, *L. vannamei* grow-out farming is freshly initiated in these ponds very cautiously with stocking of Specific Pathogen Free *L. vannamei* PL bought from hatcheries.



*Close view of PL 10-15mm*



*Subrato Ghosh with Scampi seed producer*

## Aqua farmers worried over manufacturers' attempt to increase shrimp feed prices



*A worker sprinkling feed in a shrimp pond at Rayavaramu village, near Tanguturu, in Prakasam district. KOMMURI SRINIVAS*

N.S. Chowdary, Ongole: Amid rising production costs, shrimp feed manufacturing companies have proposed to increase the prices again.

Aqua farmers across the State have requested Chief Minister N. Chandrababu Naidu, who is also Chairman of the Andhra Pradesh State Aquaculture Development Authority (APSADA), to intervene and stop the move to increase the price.

According to the sources, the manufacturers have decided to increase the prices by Rs 12 per kg on Vannamei shrimp feed and 14 per kg for tiger shrimp feed.

This follows rise in prices of fish meal, fish oil, minerals, binders, soy bean, and other raw materials used in the manufacture of the feed during the three-month period from January 26 to April 26.

The manufacturers have written a letter to the AP Fisheries Commissioner

and APSADA to give permission for the proposed price rise. However, the aqua farmers are opposing the move as the prices have already been increased by Rs 4 per kg in February, citing hike in the production cost.

Mr Duggineni Gopinath, president of Prakasam District Shrimp Farmers' Association, says, "The shrimp feed manufacturers have become a syndicate and are preparing to increase the feed prices again to burden the aqua farmers. The Chief Minister should reject the proposal and help the aqua farmers."

"Currently, shrimp farmers are facing increasing production cost and their cultivation is not profitable. On the other hand, the shrimp kept in ponds are dying due to various viruses. In this situation, the feed manufacturing companies have formed a cartel and are seeking permission for price hike again," he observes. In fact,

the prices of raw materials have not increased as much as the companies claim. Every year, from April 15 to June 14, the government imposes a ban on fishing, during which period the supply of fish meal and fish oil is low. Also, the farmers who grow soybean receive their harvest in November and December, when the price is less, reasons association secretary B. Ramesh Reddy. The price will increase marginally in the months of February, March and April. Citing this as a reason, the feed

manufacturing firms are attempting to increase the prices of shrimp feed and make more profits, he argues.

If the feed prices are increased, the shrimp farmers who do not have remunerative prices will completely avoid shrimp farming, and it will lead to the collapse of the aqua industry, fears association vicepresident Ch. Ramanaiah.

The association leaders have also urged the government to provide power subsidy to all shrimp farmers by reducing the tariff to 1.50 per unit.

## Rs 1,000 crore allocated for canal works in phases: Ramanaidu



**Vijayawada:** Water Resources Minister of A.P. Nimmala Ramanaidu on May 15 said the canal system in the State had deteriorated badly during the five years of the YSRCP rule as it neglected essential maintenance works. Reviewing the progress of Operation and Maintenance (O&M) works and the Veligonda Project through a video-conference with irrigation officials, the Minister said the NDA government had allocated Rs 708 crore in two phases during its very first year for O&M activities.

He announced that an additional Rs 397 crore had now been sanctioned in the third phase for urgent canal repair and restoration works, including desilting, removal of weeds and aquatic growth, and other emergency maintenance activities. The Cabinet had already approved a mechanism to fast-track emergency irrigation works exceeding Rs 10 lakh through short-term tenders within seven days to avoid delays. Out of a total of 6,502 maintenance works taken up across the State, nearly 5,943 works, around 91%, were being executed through Water Users' Associations, he said. The Minister directed irrigation officials to closely monitor the works and ensure their completion before the commencement of the kharif season.

## White Feces Syndrome: Latest understanding and preventive measures

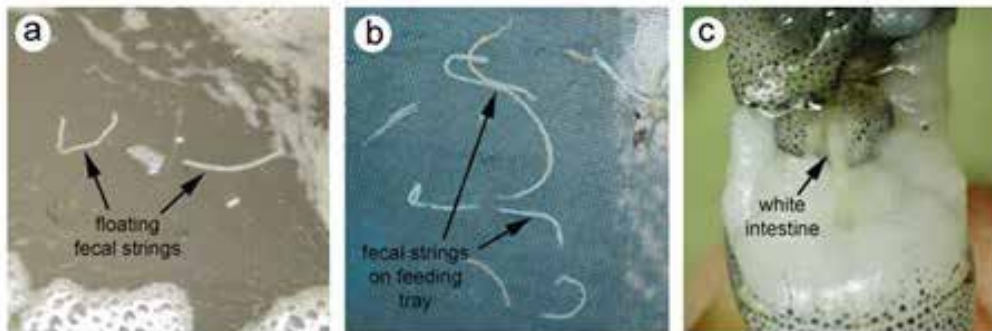


Figure 1: Source: Sriurairatana et al. (2014)

Firstly described around 2010, **White Feces Syndrome (WFS)** is an important disease for **shrimp farming** in Asian countries that can cause severe mortalities and economic losses. This disease is a complex syndrome whose occurrence remains unclear. The factor triggering WFS is yet unknown and this might not be the result of one single agent. Description, aetiology, and preventive measures: Techna's experts give an update.

**White Feces Syndrome: A syndrome that causes mortality and reduce performances. The White Feces Syndrome** refers to the presence of floating white fecal strings in ponds. It can be observed in both farm-reared **Black tiger shrimp** (*Penaeus monodon*) and **Pacific white shrimp** (*Litopenaeus vannamei*). **The syndrome causes several issues**, including high mortality, growth retardation, size heterogeneity, and an elevated feed conversion ratio. Survival is generally reduced by 20-30% (Tamilarasu et al., 2020) and cumulative mortalities

can be as high as 50% in the summer period (Hou et al., 2018). Early **disease indications** (floating fecal strings) appear in feed trays and at the water surface (figures 1a-1b), with a sudden reduction in feed consumption. It usually happens in grow-out ponds around the second month after stocking.

substance (figure 1c). Also, a loose exoskeleton and dark-coloured gills can be observed.

**But these feces are not "true" feces. While normal ones are mostly composed of undigested feed, the white feces are composed of leftovers of tissues from hepatopancreas,**

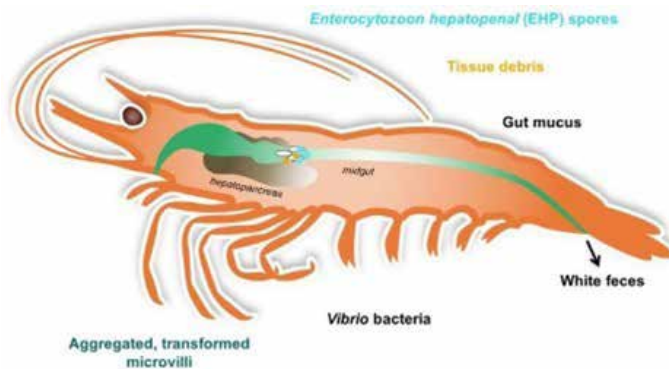


Figure 2 - Source: Techna

Figure 2: Source: Techna

The shrimp feces turn from normal (a brownish colour) to a pale white colour, leading to the name of this disease. White feces appear to be more buoyant than normal feces and float on the water's surface. The shrimp hepatopancreas also becomes whitish, soft, and looks empty due to the lack of feed. The midgut is distended and filled with white to yellow

**gut mucus**, and frequently contain a mixed bacterial component and a massive

number of spores from the microsporidian parasite *Enterocytozoon hepatopenaei* (EHP) (Pachumwat et al., 2021). *Vibrio* species have also been found in the feces of infected shrimps (Suguna, 2020). When the **contents of the gut or fecal strings** were examined with a light microscope, they consisted of masses of vermiform bodies that looked like protozoan gregarines (Sriurairatana et al., 2014). This explains why at some point, it was supposed that gregarines were the causative agents of WFS.

Sriurairatana et al. (2014) described the White Feces Syndrome as coming from a disorder in the microvilli from epithelial cells of the hepatopancreas. Transformed microvilli, peeled away, are collected in the tubule lumens and aggregated together as vermiform bodies. **Stripped of microvilli**, cells undergo lysis. The vermiform bodies are almost transparent with no cellular structure. They accumulate with tissue debris, mucus, EHP spores, and eventually *Vibrio* bacteria at the hepatopancreas-midgut junction and in the midgut. These aggregated and transformed microvilli lead to the formation of white fecal strings, which are finally excreted (figure 2).

Histology performed by

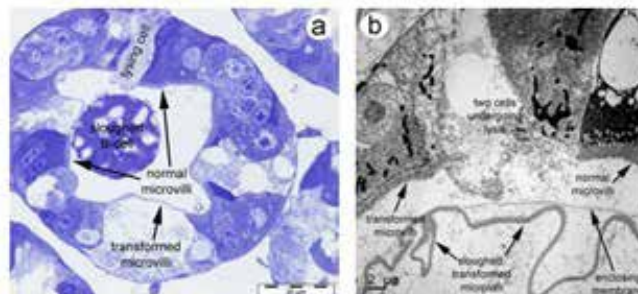


Figure 3: Source: Sriurairatana et al. (2014)



# AQUACULTURE PROBIOTICS EXPERT



**Nu Ri**  
NET 200 g **BSL**

**Probiotics**  
for water treatment

### 1. WATER QUALITY CONDITIONING

Best choice of *Bacillus* spp. that rapidly decompose uneaten feed, feces and other organic substances in pond water, keeps water quality optimal



### 3. ESTABLISH BALANCED POND BACTERIA SYSTEM

Complete nutrition with vibrio and inhibit them to grow. Provide nutrition for probiotics in the pond, to establish a well-balanced Farming system.



### 6. INCREASE AQUACULTURE PRODUCTION

Good quality of water prevents fish/prawn infections, making high profit of production

### 2. HIGH ACTIVITY OF SPORES

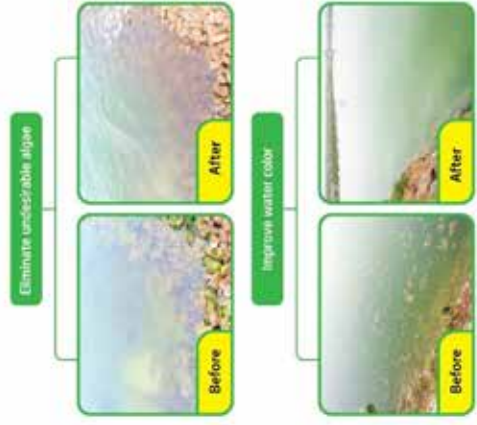
No cultivation is needed. Easily adapt to the changes of surroundings and grow fast in freshwater or seawater culture farming, even under low oxygen environment

### 3. DECREASE AMMONIA CONTENT

Prevent the accumulation of toxic substances such as  $NH_4$ ,  $NO_2$ , etc.

### 4. IMPROVE WATER COLOR

Improve water color regulate the algae and bacteria balance in water, turning your pond from green to clear



### \* COMPOSITION:

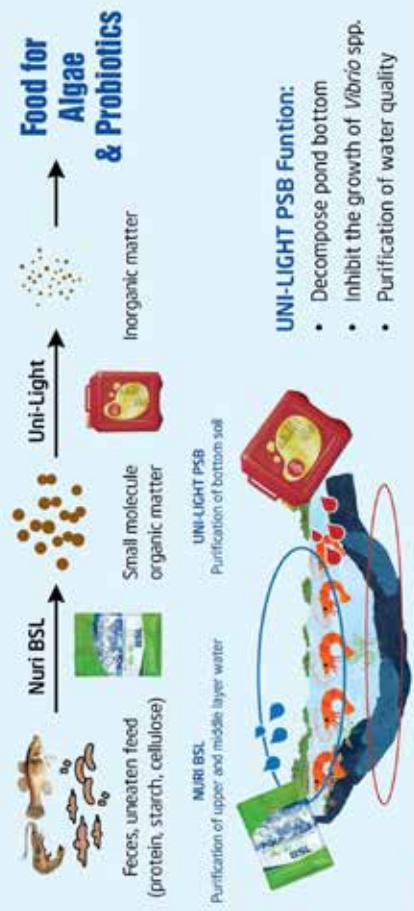
- Bacillus spp.** >  $1 \times 10^{11}$  cfu/kg (15%)  
(*Bacillus subtilis*, *Bacillus amyloliquefaciens*, *Bacillus licheniformis*)
- Carrier (rice bran, corn gluten) (75%)
- Moisture (10%)

### \* STORAGE:

Keep at dry, well-ventilated condition. Avoid direct sunlight exposure and use as soon as possible once opened for best quality.

### \* DIRECTION OF USE:

No cultivation is needed. Apply Nuri BSL with water-soluble bag near to the working water wheel or pour into the pond evenly. Recommend apply Uni-Light PSB together with Nuri-BSL on sunny day to achieve a clear pond more efficiently.



### BSL Dosage:

Quantity /10,000 m <sup>2</sup>	10 - 30 pl/m <sup>2</sup> tiger prawn or < 80 pl/m <sup>2</sup> Vannamel	For > 30 pl/m <sup>2</sup> tiger prawn or > 80 pl/m <sup>2</sup> Vannamel	For > 150 pl/m <sup>2</sup> Vannamel
7 days before stocking	800 g - 1,000 g	1,200 - 1,500 g	1,200 - 1,500 g
Day of stocking	300 g - 500 g	800 g - 1,000 g	800 g - 1,000 g
Every 7 - 10 days after stocking	300 g - 500 g	800 g - 1,000 g	3 - 5 days / use 1,000g - 2,000g

\*\*\*Dosage can be adjusted according to the water conditions and practices.

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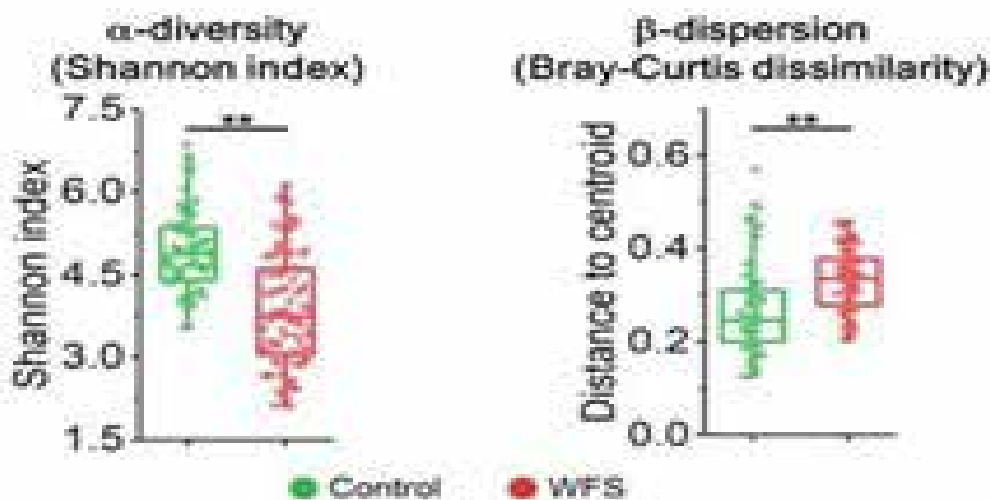


Figure 4: Source: Huang et al. (2020)

Sriurairatana et al. (2014) on a cross-section of hepatopancreas tubule (figure 3a) shows a modified, sloughed B-cell in the lumen with microvilli spread over its surface. Epithelial cells with normal microvilli and others with abnormally thin layers, or denuded of microvilli, with lysis process ongoing were also seen.

By transmission electron microscopy (figure 3b), hepatopancreas epithelial cells show normal and transformed microvilli and an early stage in the aggregation of transformed and sloughed microvilli surrounded by an enclosing membrane. After, aggregated transformed microvilli form gregarine-like entities.

**Environment, microbiota and stressful conditions: key factors** White Feces Syndrome is a syndromic condition of complex etiology, similar to diarrhea in humans (Pachumwat et al., 2021), and its origin is still unclear. A recent study shows that a full intestinal ecosystem alteration, rather than a single pathogen, is

associated with WFS (Huang et al., 2020). On the other hand, many studies show an **important impact of the environment and stressful conditions on this syndrome**. These adverse conditions can also facilitate the development of opportunistic pathogens and create an unbalanced digestive bacterial community. Furthermore, anti-nutritional factors, toxins such as mycotoxins contained in feeds might create damage to the hepatopancreas, thus promoting degraded hepatopancreas conditions that favour the occurrence of WFS.

Like humans, the **shrimp digestive system** hosts a large number of microorganisms dominated by bacteria, which constitute a complex microbial ecosystem called the microbiota. It has multiple functions and plays an important role in maintaining host health, nutritional absorption or immune response. The balance in the intestinal microbiota population is crucial and the loss of microbial diversity in the

intestine can cause host disease.

Recent studies (Hou et al., 2018 and Huang et al., 2020) reported a close relationship between dysbiosis of the intestinal microbiota and **White Feces Syndrome**. According to these authors, the intestinal bacterial communities of white feces-affected shrimp are significantly less diverse and more heterogeneous than normal shrimp (represented respectively by Shannon index and Bray-Curtis dissimilarity on figure 4).

**The profile of the intestinal bacterial community is significantly different between healthy and white-feces-affected shrimp.** According to Huang et al. (2020), increased abundances of opportunistic pathogens (*Vibrio*, *Candidatus Bacilloplasma*, *Aeromonas*, and *Photobacterium* species) and decreased abundance of beneficial bacteria (*Chitinibacter* spp.) were the common features associated with white feces affected shrimp. Furthermore, this study

demonstrated that the transplantation of intestinal microbiota from white feces-infected donors to healthy shrimp leads to similar symptoms in about one-third of cases. Hou et al. (2018) reported that the overgrowth of intestinal *Candidatus Bacilloplasma* and *Phascolarctobacterium* species and depression of *Paracoccus* and *Lactococcus*, known to be beneficial to the host, might result in the occurrence of WFS.

**White Feces Syndrome** is often associated with the microsporidian EHP whose spores were found in and around the transformed microvilli. As described by Huang et al (2020), the microsporidian was first proposed as the causality of WFS but this hypothesis was not supported by subsequent study). Recently, Pachumwat et al. (2021) showed that EHP may be a component but not the only causative agent. According to Sathish Kumar et al. (2022), WFS is a shrimp diarrhea associated with severe EHP infection that may be caused by a combination of unknown agents.

The severe **loss of microvilli** may predispose shrimp to other enteric pathogens. The study by Somboon et al. (2012) indicated that most of the shrimp that had white feces had significantly higher amounts of *Vibrio* bacteria, including *V. vulnificus*, *V. fluvialis*, *V. parahaemolyticus*, and *V. alginolyticus*, in their hemolymph and intestine, than in control shrimp.

**Preventive measures** Even though the exact causative agent or factor



Figure 6: Source: Techna

triggering WFS is unknown, some actions could be taken to avoid its outbreak or, at least, reduce the severe impacts and losses of this syndrome. We can divide possible actions into two different categories, the shrimp and its environment.

It has been proven that WFS first targets the hepatopancreas cells of shrimp. Therefore, promoting a better condition of this organ could help counter the WFS effects. This could be done by using a high-quality, highly digestible feed. Quality ingredients and proper formulation will lead to facilitated digestion and less demand on the hepatopancreas which could be more resilient.

Choosing raw materials that contain low levels of toxins or anti-nutritional factors is also important; as these compounds will directly affect hepatopancreas. Indeed, this organ handles a lot of the toxins in the animal.

Furthermore, the feeding ratio should be adapted. High feeding rates are

stressful for the animal and its digestive system. Lowering the amount of feed during risky periods is as important as the feed quality.

We've seen that WFS impacts and losses are mostly caused by opportunistic pathogens such as EHP or Vibrio bacteria. Specific additives could be used to limit the proliferation of these pathogens in the digestive gut of shrimp. The immunity of the animals could also be increased by the use of specific ingredients, called immune stimulants. Thanks to its long-time experience and knowledge in the field of additives; Aquaneo designed a product called WF Detox. It helps the shrimp's immune system and has actions on the pathogens and overall microbial population of the digestive tract (see figure 5). WF Detox also incorporates plant extracts that prevent membrane degradation and help toxin excretion. These actions aim at an improved hepatopancreas status. WF Detox should be used as a

preventive additive when conditions are in favour of WFS outbreak. It can also be used at higher doses when WFS is present in the ponds.

Besides **shrimp**, the **environment** also needs to be considered. Indeed, pond is a complex ecosystem that has a direct impact not only on the animals, but also on the surrounding pathogens. It is important to monitor parameters and adapt farming practices accordingly.

First, high temperatures (Tamilarasu et al., 2020), but also fast temperature fluctuations induce stress to the animals that could help the WFS outbreak or increase its severity.

Other important parameters to monitor include: pH, alkalinity, ammonia, nitrite, and oxygen levels. Similarly, maximum and/or minimum levels as well as strong fluctuations could favour the WFS outbreak or increase its severity. High densities, poor pond-bottom quality, and high planktonic blooms are

also negatively affecting environmental quality and animals.

Feeding and feed quality also have an impact on the environment as the undigested part will remain in the ecosystem, polluting it and ensuring conditions for the growth of opportunistic pathogens. As already mentioned above, feeding should be adapted and reduced when risk increases (values close to the limits and strong fluctuations).

Proper Biosecurity measures are also important to keep pathogens as low as possible in the environment. As we've mentioned before, opportunistic pathogens could have a very strong impact in the case of WFS outbreak.

The last thing to keep in mind is to adapt & anticipate. Indeed, prevention is more effective and less expensive than cure. Farm management should be adapted according to the conditions. For example, ammonia toxicity is different according to pH and temperature. Therefore, the ammonia limit should be adapted according to these parameters. Furthermore, if the ammonia level is increasing, don't wait until it reaches the limit to take action; anticipate.

Feeding should also be adapted to the overall pond conditions and not only shrimp size and temperature. Feed choice or the use of additives such as WF Detox should be linked with the risk of WFS outbreak.



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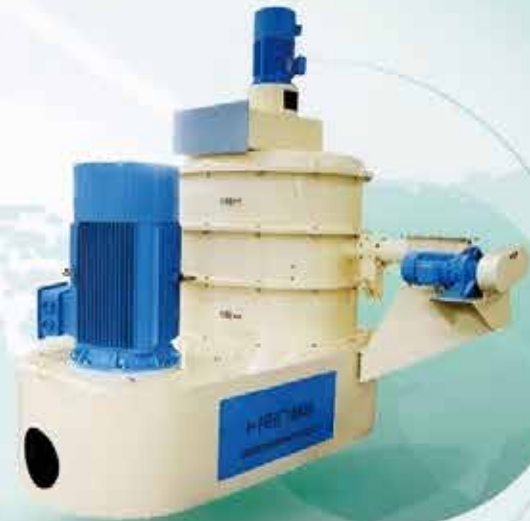
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# Fish as a Superfood: Nutrition and Health Benefits for All Ages

Arun Konduri<sup>1</sup>, Divya Banothu<sup>1</sup>, Tao Kara<sup>2</sup>, Raveendar Banothu<sup>1</sup>, Shyam Prasad. M<sup>\*</sup>, Narra Mohana Swapna<sup>3</sup>

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## Highlights

- Aquatic animal foods provide highly digestible protein with lower caloric density and higher omega-3 long-chain polyunsaturated fatty acids (n-3 LC PUFA) compared to terrestrial animal sources.
- Rich source of high-quality protein, essential amino acids, vitamins A and D, B-complex vitamins, and vital minerals such as iodine, selenium, and zinc.
- Fish and fish oil are excellent sources of omega-3 fatty acids, particularly EPA and DHA, especially abundant in fatty fish species.
- Fish-derived proteins and bioactive peptides exhibit ACE-inhibitory, immunomodulatory, antioxidant, antimicrobial, and anticoagulant properties.
- Regular consumption supports neurodevelopment, cardiovascular health, immune function, and overall physical and cognitive performance across all age groups.
- Contributes to nutritional security and strengthens public health through increased dietary inclusion of fish.

## 1. Introduction

According to FAO (2024), global apparent consumption of aquatic animal foods was estimated at 165 million tonnes in 2022, corresponding to an average of 20.7 kg per capita. This steady rise in fish consumption has significantly shaped dietary patterns and contributed to improved public health worldwide. Fish is

widely regarded as a vital component of the human diet and is frequently categorized as a “superfood” owing to its exceptional nutrient profile. It is a rich source of high-quality protein, essential amino acids, fat-soluble vitamins (A and D), water-soluble B-complex vitamins, and key minerals such as iodine, selenium, and zinc. Aquatic animal foods are a rich source of protein and have a lower caloric density, and have a high content of omega-3 long-chain polyunsaturated fatty acids (n-3 LC PUFA) compared to land-living animals (Tacon and Metian, 2013). These nutrients are highly bioavailable, contributing significantly to human growth, development, and overall health. Distinct from many other animal protein sources, fish is the primary dietary source of long-chain omega-3 polyunsaturated fatty acids, namely eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These compounds have been extensively documented to support neurodevelopment, enhance cognitive performance, reduce the risk of cardiovascular diseases, and modulate immune functions. Regular fish consumption provides health benefits across all age groups, from infants requiring DHA for brain development to elderly individuals seeking cardioprotective and anti-inflammatory effects. Furthermore, epidemiological studies consistently associate habitual fish intake with a lower prevalence of chronic non-communicable diseases, improved metabolic regulation, and enhanced psychological well-being. Collectively, these findings underscore the classification of fish as a functional food with profound implications for nutritional security and sustainable health promotion in modern

societies.

## 2. Nutritional Value of Fish

### 2.1. Protein Powerhouse

Fish protein has long been considered to have a high nutritional value (Sargent, 1997). In addition, aquatic protein is highly digestible and rich in several peptides and essential amino acids that are limited in terrestrial meat proteins, as methionine and lysine, as suggested by Tacon and Metian (2013). Fish protein hydrolysates are considered superior from a nutritional standpoint due to their excellent amino acid composition and easily digestible proteins. Fish is recognized as a high-quality source of animal protein, notable for its easy digestibility and lower connective tissue content compared to red meat. Its protein fraction possesses a well-balanced amino acid composition, making it a vital dietary component for many populations worldwide (Harnedy and FitzGerald, 2012). Fish protein supports muscle development, tissue repair, and sustained energy supply, thereby contributing significantly to human nutrition and health. Based on biochemical classification, fish proteins can be grouped into three main categories (FAO, 2020):

#### A. Structural (myofibrillar) proteins

– including actin, myosin, tropomyosin, and actomyosin, which account for 70–80% of the total protein content.

**B. Sarcoplasmic proteins** – consisting of myoalbumin, globulins, and enzymes, contributing about 20–30%.

#### C. Connective tissue proteins

– primarily collagen, which constitutes ~3% in teleosts and up

# Panel Discussion


Experts - Farmers Interaction Meet

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**Venue:** Kotla Function Hall, Undi Road,  
Bhimavaram, Andhra Pradesh, India

Exhibition Timings: 10 AM to 6 PM

### Panel Discussion & Interaction Meet

Experts and Consultants in Aquaculture are invited to take part in Panel Discussion and answer to the queries and issues of the farmers during the meet on 12 June 2026

### Advantages of Farmers' Participation in the Expo

Farmers can directly meet and talk to the companies, who exhibit their products & services in the stalls and know about the products and their usefulness in shrimp and fish culture. Companies (Exhibitors) can meet farmer-customers and get their feedback on their products and performance as well as services. This will enable the companies / manufacturers to know farmers' feedback and suggestions to further improve the quality of their products and services. Every product displayed in Aquaculture Expo and every word spoken in the inaugural session and during the technical interaction are meant for farmers and the culture. Farmers can also interact with experts on various aspects and get solutions for various problems in Aquaculture. This Expo is also a very good opportunity to the enterprising people who would like to take up Aquaculture as a profession.



**Exhibition Timings:** 10:00 AM to 6:00 PM on June 12 & 13

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to 10% in elasmobranchs.

A detailed distribution indicates that fish proteins typically comprise 66–77% myofibrillar proteins (myosin, actin, actomyosin, troponin), 20–30% sarcoplasmic proteins (mainly albumins and hemoproteins), and 3–5% stromal proteins (collagens) (Gates, 2016). These proteins exhibit superior water-holding capacity, emulsification, and gelling properties, making them highly valuable for the fish processing industry (Taheri et al., 2013). Commercially, fish species are classified based on crude protein content into four categories: below 10%, 10–15%, 15–20%, and above 20% (Sikorski, 2012). Finfish and shellfish are vital dietary protein sources. Collectively, aquatic animal foods contribute around 15% of global animal protein and 6% of total protein intake, while also providing essential nutrients, including omega-3 fatty acids, vitamins, and minerals (FAO, 2024).

### 2.2 Omega-3 Fatty Acids: The Star Nutrient

Fish and fish oil are rich dietary sources of omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are predominantly found in fatty fish species (Kris-Etherton et al., 2002). Epidemiological evidence indicates that men who consumed fish at least once per week experienced a 50% reduction in the risk of sudden cardiac death, along with a significant decrease in all-cause mortality (Albert et al., 1998). Similarly, consumption of approximately 5.5 g of omega-3 fatty acids per month, equivalent to one weekly serving of fatty fish, was associated with a 50% reduction in the risk of primary cardiac arrest (Siscovick et al., 1995). Clinical investigations further demonstrated that patients receiving 1.5 g of fish oil per day for two years exhibited increased regression and decreased progression of coronary atherosclerotic lesions (Schacky et al., 1999). Fish remain a virtually unique and abundant source of omega-3 long-chain polyunsaturated fatty acids ( $\omega_3$  LC-PUFA) in the human diet

(Tocher, 2009). Fishes are enriched in EPA and DHA (Khan et al., 2017), which play critical physiological roles. These fatty acids are essential for brain development, maintenance of visual acuity, and cardiovascular health, making them especially important for children, pregnant women, and elderly populations.

### 2.3 Vitamins and Minerals

Fish is valued not only for its high-quality protein but also for its impressive micronutrient profile. It provides essential vitamins, such as vitamin D and vitamin B2 (riboflavin), and is rich in calcium and phosphorus, along with important minerals including iron, zinc, iodine, magnesium, and potassium (Washington State Department of Health, 2025). In populations with limited alternative dietary sources, fish can also provide significant amounts of vitamin A, iron, and zinc (Lund, 2013). Furthermore, fish is an excellent source of vitamin D, selenium, phosphorus, and calcium (Tilamia and Sampels, 2017). The recommended daily intake of vitamin D is at least 1000 IU (25  $\mu$ g), which can be effectively met through fish consumption (Lu et al., 2007; Holick, 2008). Importantly, fish contain vitamin D3 (cholecalciferol), the biologically active form in humans, and its concentration varies considerably among species, ranging between 0.5 and 30  $\mu$ g/100 g of fish muscle (Mattila et al., 1995).

Among the essential nutrients supplied by fish consumption, selenium stands out as one of the most important, ranking 17th out of 25 major dietary contributors in the USDA National Nutrient Database (Ralston, 2008). Alongside dairy products, fish and even fish bones contribute significantly to dietary calcium intake, with studies showing that calcium absorption from fish is comparable to that from skimmed milk (Hansen et al., 1998). Similarly, Martínez-Valverde et al. (2000) highlighted fish and other aquatic animals as rich sources of calcium, reporting average concentrations of 68–126 mg/100 g in crustaceans, molluscs, and fish, compared to

only ~14 mg/100 g in terrestrial meats (Tacon and Metian, 2013). Additionally, the bones of salmon and cod have been identified as particularly good sources of highly bioavailable calcium (Malde et al., 2010).

Phosphorus is another essential mineral abundantly found in fish. Several studies suggest that fish provide 204–230 mg/100 g of phosphorus, surpassing the average of 176 mg/100 g typically found in terrestrial meats (Martínez-Valverde et al., 2000; Tacon and Metian, 2013). The importance of macrominerals such as calcium, phosphorus, magnesium, sodium, potassium, and chloride, as well as trace elements including cobalt, copper, iodine, iron, manganese, selenium, and zinc, has been well established in fish (National Research Council, 2011). These findings collectively emphasize that fish are superior sources of multiple essential vitamins and minerals, making them indispensable contributors to balanced nutrition and overall health.

### 2. Health Benefits of Eating Fish

Eating fish regularly provides a wide range of health benefits. Numerous studies have established strong associations between fish and marine fish consumption and positive health outcomes, including a reduced risk of coronary heart and cardiovascular diseases, lower incidence of inflammatory disorders such as arthritis, and cancer prevention (Dyerberg, 1985; Calder, 2004; Rudkowska et al., 2010; Lund, 2013). Fatty fish are particularly rich in omega-3 fatty acids, which are vital for optimal body and brain function and are strongly linked to a decreased risk of many chronic diseases. Research consistently demonstrates that fish consumption is associated with lower rates of coronary heart disease (CHD) and reduced mortality. Omega-3 fatty acids are essential for growth and development. Among them, docosahexaenoic acid (DHA) plays a crucial role in brain and eye development, while eicosapentaenoic acid (EPA) is especially important during pregnancy, supporting heart



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health and immune function during fetal development. For this reason, adequate intake of omega-3 fatty acids is often recommended for pregnant and breastfeeding women. However, caution is necessary, as certain fish species contain high levels of mercury, which is associated with neurodevelopmental issues. Beyond cardiovascular and developmental health, omega-3 fatty acids have also been linked to mental well-being. A 2018 meta-analysis further reported that introducing fish into children’s diets between 6 and 9 months of age and maintaining regular intake (at least once weekly) may reduce asthma and wheezing through age 4.5 years, while fatty fish consumption may provide additional benefits in older children. Similarly, a 2019 study found that higher fish intake is associated with a lower prevalence of childhood asthma.

The health benefits of fish extend beyond the flesh itself, as fish-derived byproducts also exhibit functional properties. Fish proteins, including albumin and bioactive peptides, contribute to numerous physiological functions, such as inhibition of angiotensin-I-converting enzyme (ACE), improved nutrient utilization, immunomodulatory effects, and anticoagulant, antioxidant, and antimicrobial activities (Najafian and Babji, 2012). Fish bones are also

a valuable source of calcium and phosphorus, which play a vital role in human health and biomedical applications (Terzioglu et al., 2018). Emerging evidence highlights the role of omega-3 fatty acids in immune defence. Compounds such as DHA, EPA, ALA, and AA have been shown to protect against viral infections, including SARS-CoV, by interfering with the viral entry pathway via angiotensin-converting enzyme-2 (ACE2). In fact, salmon and sablefish have shown potential to reduce COVID-19 severity (Baral et al., 2022). Similarly, fish-derived nutrients such as PUFA, EPA, and DHA are known to enhance cognitive function and thinking ability, and fish oil supplementation has been reported to lower the risk of dementia (Kokubun et al., 2020).

Fish oil supplements, rich in EPA and DHA, have also been associated with protective effects against liver cancer by suppressing tumour growth factors and inhibiting nuclear signalling pathways (Guo, 2022). Furthermore, especially fatty fish species such as salmon, sablefish, sardines, fish roe, and tuna serve as primary sources of bioactive compounds, including polyphenols, omega-3 fatty acids, and essential amino acids such as  $\alpha$ -linolenic acid (ALA), all of which play a significant role in combating obesity-related

disorders (Noreen et al., 2025).

#### 4. Fish for All Ages

Fish consumption provides essential nutrients that benefit individuals across all age groups. For infants and children, fish can be introduced after six months in small, safe portions. It supports rapid brain growth, strong bones, and healthy eyesight. Oien et al. (2010) reported that infants who ate fish once a week or more were 38% less likely to have eczema at 2 years of age. Similarly, a 2013 meta-analysis of three studies found that fish consumption in infancy was inversely related to childhood asthma incidence, with children who ate the most fish having a 25% lower risk of developing asthma than those who ate the least (Yang et al., 2013). Moreover, higher seafood intake, especially fish, in childhood and adolescence, particularly when consumed boiled, was associated with a lower risk of obesity (Zhang et al., 2024).

Among adults, fish plays a crucial role in preventing lifestyle-related diseases such as obesity, diabetes, and cardiovascular problems, while helping to maintain fitness and stamina. Pregnant women particularly benefit from fish consumption, as it provides DHA, which supports fetal brain and eye development and enhances maternal nutrition and immunity. Research indicates that prenatal exposure to nutrients in fish improves neurocognitive development, including IQ, communication, and other developmental outcomes (Hibbeln et al., 2007). Furthermore, a study funded by the NIH’s ECHO Program found that eating any number of fish during pregnancy was associated with a 20% lower likelihood of autism diagnosis in offspring, particularly females, along with a slight reduction in autism-related traits.

For the elderly, regular fish consumption helps prevent memory loss, weak bones, and joint problems, while also reducing the risk of stroke, heart disease, and age-related vision loss. It positively impacts thyroid homeostasis, supports

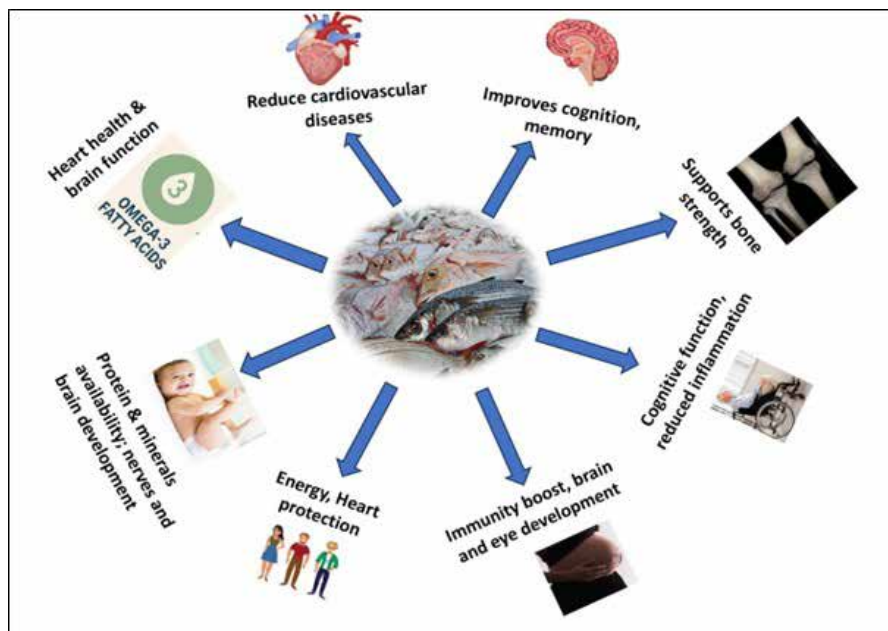


Figure 1: Fish as a Superfood: Nutrition and Health Benefits for All Ages



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healthy body weight maintenance, reduces age-associated increases in blood pressure, and improves glucose regulation, thereby helping to prevent diabetes and metabolic syndrome. Additionally, it helps preserve muscle mass in older adults (Mendivil, 2021). An extra serving of fish has been shown to significantly reduce the risk of metabolic syndrome, especially among older populations (Torrís et al., 2016), while fish oil-derived n-3 PUFA therapy has been demonstrated to increase muscle mass and function in healthy elderly individuals (Smith et al., 2015). The overall benefits of eating fish are shown in Image 1.

### 5. Conclusion

This article emphasizes the significance of fish as a superfood that supports health and nutrition throughout life. Rich in high-quality protein, essential fatty acids, vitamins, and minerals, fish contribute to growth, development, and disease prevention from infancy through old age. Regular consumption promotes neurodevelopment in children, supports physical and cognitive performance in youth, reduces the risk of lifestyle-related diseases in adults, enhances maternal and fetal health during pregnancy, and helps preserve cognitive and physical functions in the elderly. Overall, the paper concludes that fish is a vital functional food with significant potential to improve public health, ensure nutritional security, and promote healthy ageing when incorporated into the human diet.

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# Optimizing Protein Levels in Shrimp Feed: Evidence from Multi-Pond Commercial Trials in Thailand

Commercial farm data show that reducing dietary protein can maintain shrimp performance while improving feed efficiency, profitability and environmental sustainability

By Dr Lumpan Poolsawat, Dr. Natthinee Munkongwongsiri and Dr Craig L. Browdy



*Dr Craig L. Browdy*

Protein is one of the most expensive components in shrimp feed, yet it is often used at levels higher than what shrimp actually require. Many farmers believe that higher protein diets will always result in better growth and higher production. But is this really true under commercial farming conditions?

A recent multi-pond evaluation conducted in Thailand provides new insights that challenge this long-standing assumption.

### Rethinking protein in shrimp diets

For many years, shrimp farmers have relied on high-protein diets—typically 38–45% crude protein (CP)—to



*Dr Natthinee Munkongwongsiri*

support growth and production. This approach is based on the belief that higher protein levels directly translate into better performance.

However, rising feed costs and increasing pressure to improve sustainability are challenging this assumption. The key question is no longer how much protein can be fed, but how much is actually required to achieve optimal results.



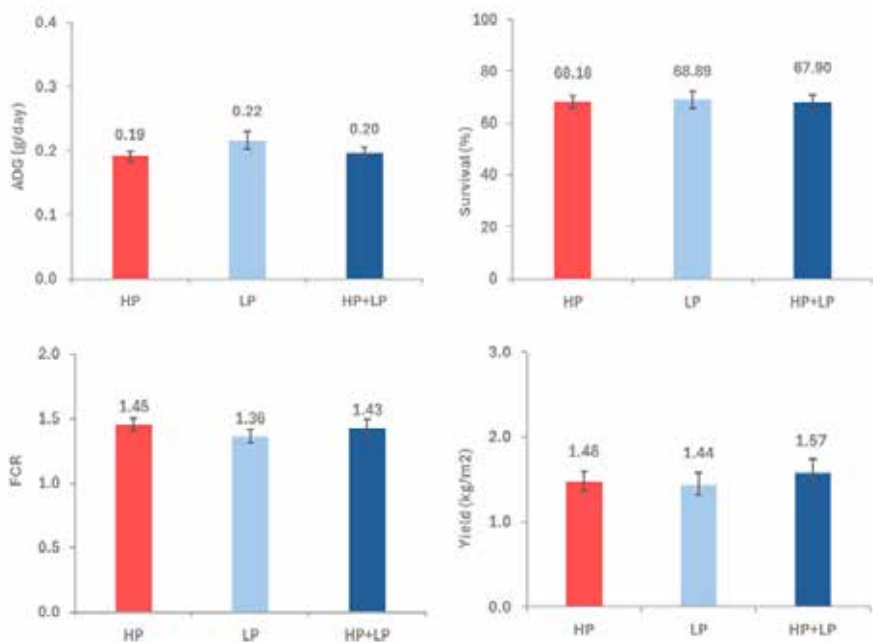
*Dr Lumpan Poolsawat*

### Evaluating feeding strategies under commercial conditions

To better understand the impact of dietary protein levels, three feeding strategies were evaluated across 76 commercial ponds in Thailand during 2025–2026:

- High protein (HP): 38% CP throughout the culture cycle
- Low protein (LP): 35% CP throughout the cycle
- Step-down strategy (HP+LP): 38% CP during early stages (DOC 1–30), followed by 35% CP until harvest

All ponds were selected based on good management practices, stable performance history, and absence of major disease outbreaks to ensure reliable comparisons.



*Figure 1: Comparison of growth performance (ADG, survival, FCR) across feeding strategies*

## DELIVERING RELIABLE PERFORMANCE UNDER DISEASES PRESSURE

Superior Performance Under EHP Challenge, Backed by Lab and Field Data

Strong recovery and growth after white feces outbreaks

Lower FCR = Optimum feed usage

High survival rate ensures profitable cycles



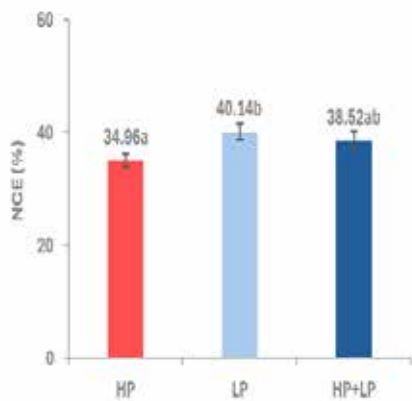


Figure 2: Nitrogen conversion efficiency (NCE) showing improved protein utilization in LP and HP+LP groups

Unlike laboratory trials, this evaluation reflects real farm conditions, making the results directly applicable to commercial shrimp production.

### Comparable performance across protein levels

Results showed no significant differences among feeding strategies in key performance indicators, including:

- Average daily growth (ADG)
- Survival rate
- Feed conversion ratio (FCR)
- Yield

These findings demonstrate that increasing dietary protein beyond a certain level does not necessarily improve shrimp performance.

For farmers, this means that higher protein diets may not provide additional production benefits when shrimp nutritional requirements are already met.

### Improved nitrogen utilization efficiency

Although growth performance was similar, shrimp fed lower protein diets showed significantly improved nitrogen conversion efficiency (NCE).

Both LP and HP+LP groups utilized dietary protein more effectively, converting a greater proportion into biomass rather than losing it as waste.

This improvement has important practical implications:

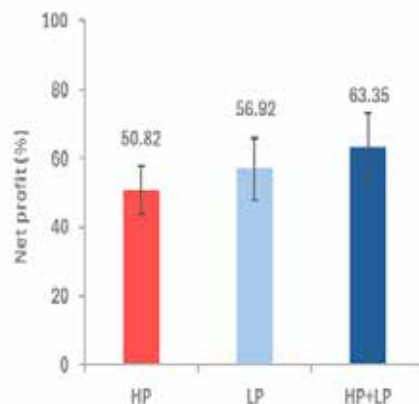


Figure 3: Net profit comparison among feeding strategies

- Reduced feed cost due to lower protein inclusion
- Lower nitrogen discharge into pond systems
- Improved water quality management

In contrast, excess protein in high-protein diets is often inefficiently used and contributes to nitrogen accumulation and water quality deterioration in the culture environment.

### Aligning feed strategy with shrimp biology

The step-down feeding strategy provided particularly valuable insights.

Shrimp fed high protein during early development and lower protein during later stages achieved:

- Equivalent growth and survival
- Improved nutrient utilization
- A trend toward higher profitability

This reflects the biological development of shrimp.

In early stages, shrimp have limited digestive capacity and require higher nutrient density. As they grow, their digestive system becomes more efficient, allowing them to utilize nutrients more effectively—even at lower protein levels.

This suggests that protein requirements should be adjusted dynamically throughout the culture cycle rather than applied uniformly.

### Economic and sustainability advantages

Optimizing protein levels offers both economic and environmental benefits.

From a cost perspective, reducing protein inclusion lowers feed formulation costs, which represent a significant portion of total production expenses.

From an environmental perspective, improved nitrogen utilization reduces waste output, helping maintain better pond conditions and reducing the risk of water quality-related stress.

Together, these benefits support a more sustainable and resilient shrimp production system.

### Practical implications for farmers

The results of this study highlight several key takeaways for shrimp farmers:

- Higher protein diets do not always improve performance
- Lower protein diets can maintain growth, survival and yield
- Stage-based feeding strategies can improve efficiency
- Optimizing protein levels can enhance profitability and sustainability

Rather than focusing on feeding more protein, farmers should focus on feeding the right amount of protein at the right stage of shrimp development.

### Conclusion

This multi-pond evaluation demonstrates that reducing dietary protein levels does not compromise shrimp performance under well-managed commercial conditions.

Low-protein and step-down feeding strategies maintained growth, survival and profitability comparable to high-protein diets while significantly improving nitrogen utilization efficiency.

These findings highlight the importance of optimizing protein levels to achieve more cost-effective and environmentally sustainable shrimp production.

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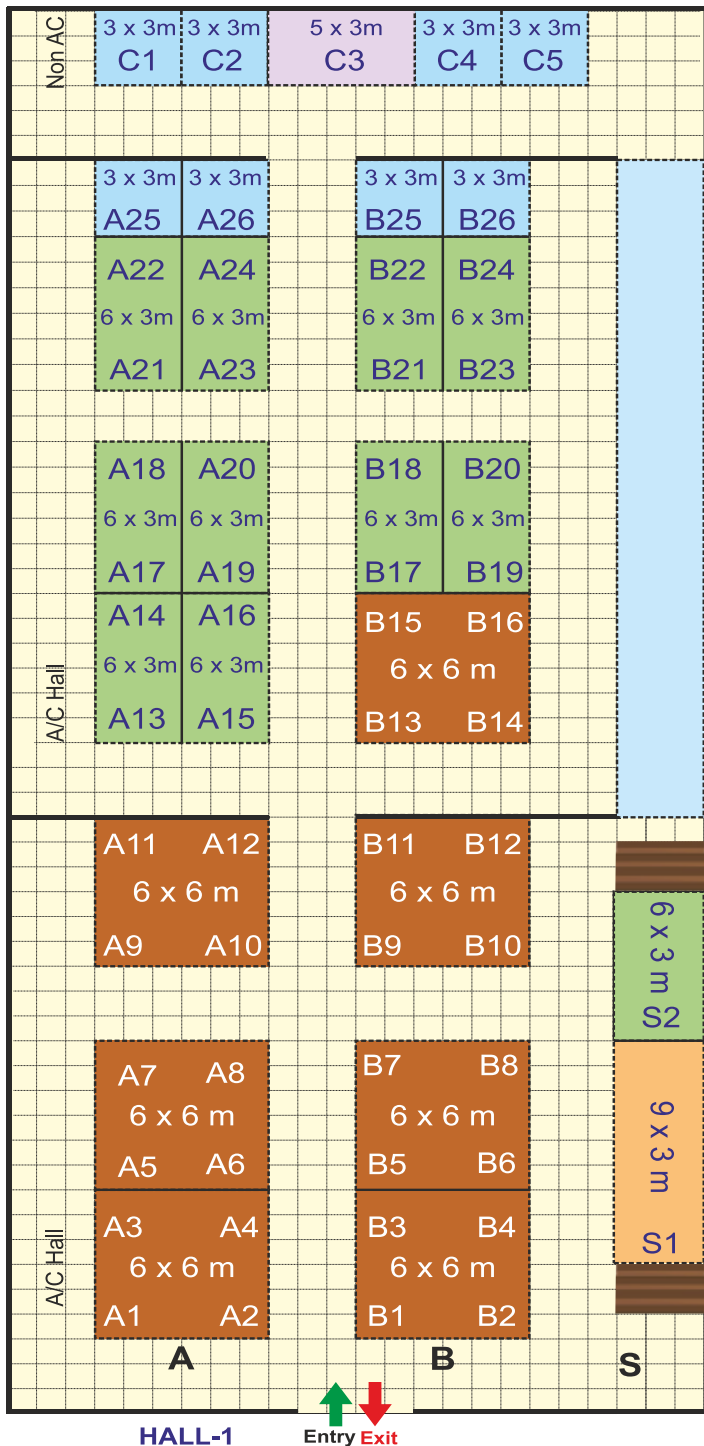
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# Artificial Intelligence in Seafood Processing: Transforming Freshness Detection, Quality Grading, and Automation for Sustainable Aquaculture

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## Key Highlights:

- AI-based fish freshness detection achieving up to 100% classification accuracy.
- Deep learning architectures such as FishNET-S for automated grading.
- Precision cutting and species classification using machine vision (98–99.7% accuracy).
- Smart packaging, IoT monitoring, blockchain traceability, and Industry 4.0 integration.
- Real-time pH sensor and machine learning applications for seafood quality assessment.
- Practical relevance for India and small-scale seafood processing sectors.
- Includes scientific figures, workflow illustrations, recent citations (2023–2025), and industrial applications.

## Abstract

Seafood processing faces persistent challenges including rapid spoilage, subjective quality assessment, labour-intensive operations, and significant post-harvest losses. Artificial Intelligence (AI) and machine learning (ML) are emerging as powerful solutions, enabling non-destructive, rapid, and accurate evaluation of freshness while automating classification and cutting processes. This review synthesises recent advancements (2023–2025) in AI applications for seafood, covering deep learning models for freshness detection (achieving up to 100% accuracy), novel architectures like FishNET-S for quality grading, machine vision systems for species classification

and precision cutting (98–99.7% accuracy), and sensor-ML integration for real-time pH monitoring. Industry 4.0 technologies, including IoT, robotics, and blockchain, further enhance traceability and

sustainability. These innovations reduce waste, improve food safety, and support small-scale processors in regions like India. Challenges such as dataset diversity, model generalisation, and workforce

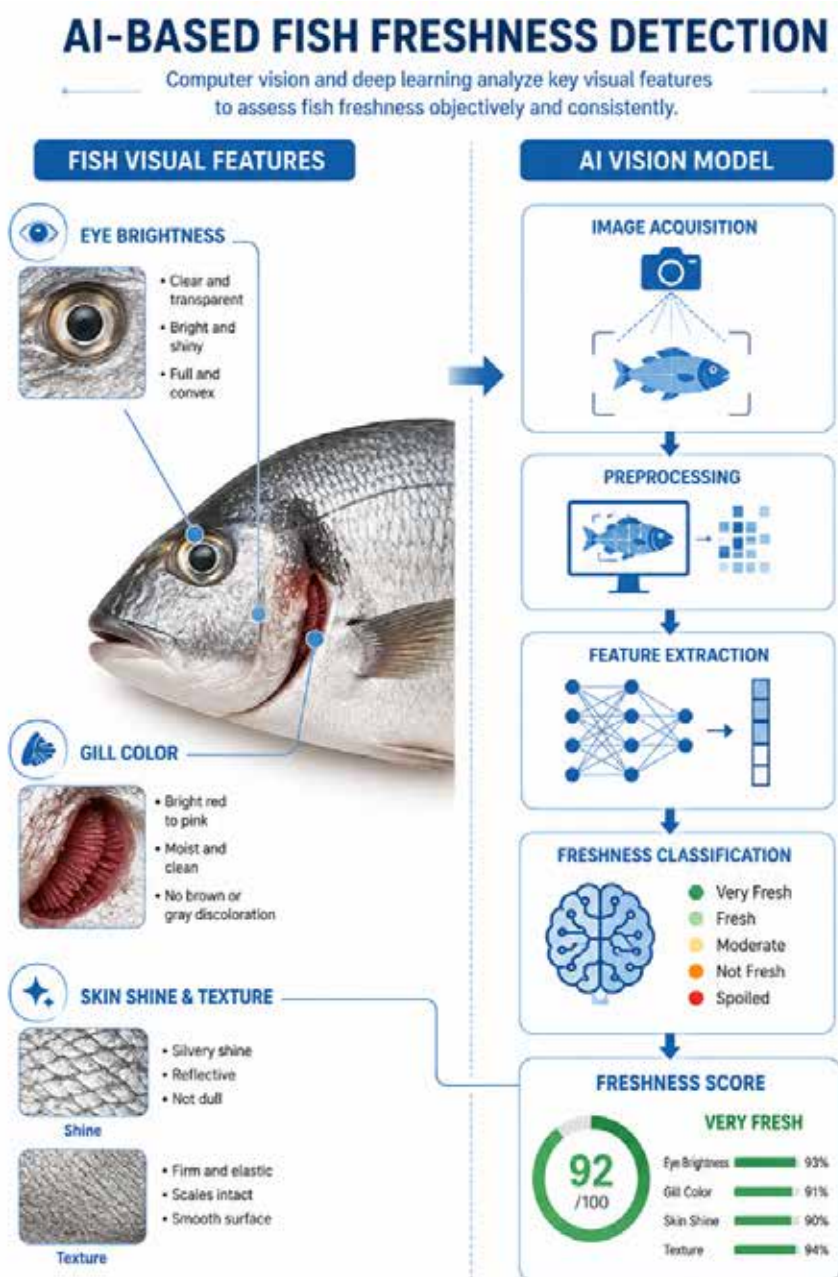


Figure 1: Fish freshness detection

# AI-BASED FISH GRADING IN SEAFOOD PROCESSING

Computer Vision • Deep Learning • Consistent Quality • Data-Driven Decisions

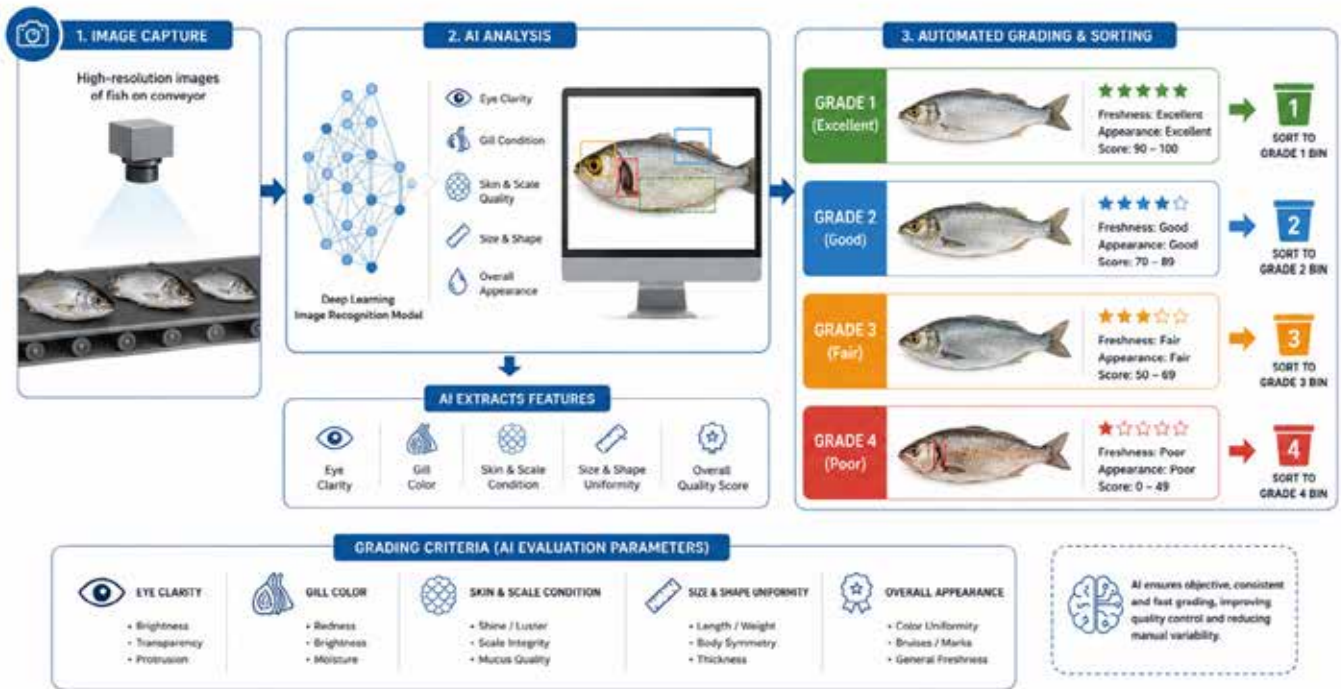


Figure 2: AI grading system

transition are discussed. AI promises to revolutionise seafood processing by shifting from reactive to predictive, efficient, and sustainable systems.

**Keywords:** Artificial Intelligence, seafood processing, fish freshness detection, machine vision, deep learning, Industry 4.0, precision

cutting, pH sensors, quality grading

## 1. Introduction

Seafood remains one of the most nutritious and sought-after protein sources globally, rich in omega-3 fatty acids, high-quality proteins, and essential micronutrients. However, its highly perishable nature leads to substantial post-harvest losses,

estimated at 20–30% in developing countries, primarily due to spoilage and inefficient processing (Kumaravel et al., 2025; Subash et al., 2024). Traditional methods of quality assessment relying on human sensory evaluation of eyes, gills, odour, and texture are subjective, time-consuming, and prone to inconsistency.

Artificial Intelligence (AI), encompassing machine learning (ML), deep learning (DL), computer vision, and sensor fusion, is transforming seafood processing. From automated freshness detection to precision robotic cutting and supply-chain traceability, AI offers objective, scalable, and real-time solutions. This article reviews key advancements published between 2023 and 2025, highlighting practical applications relevant to aquaculture powerhouses like India and Tamil Nadu.

## 2. AI for Fish Freshness Detection

Freshness is the most critical quality parameter in seafood. Yasin et al. (2023) developed a robust system using deep learning feature extractors (SqueezeNet

## AI-GUIDED PRECISION CUTTING IN FISH PROCESSING

Smart Vision • Real-time Analysis • Precise Cuts • Higher Yield

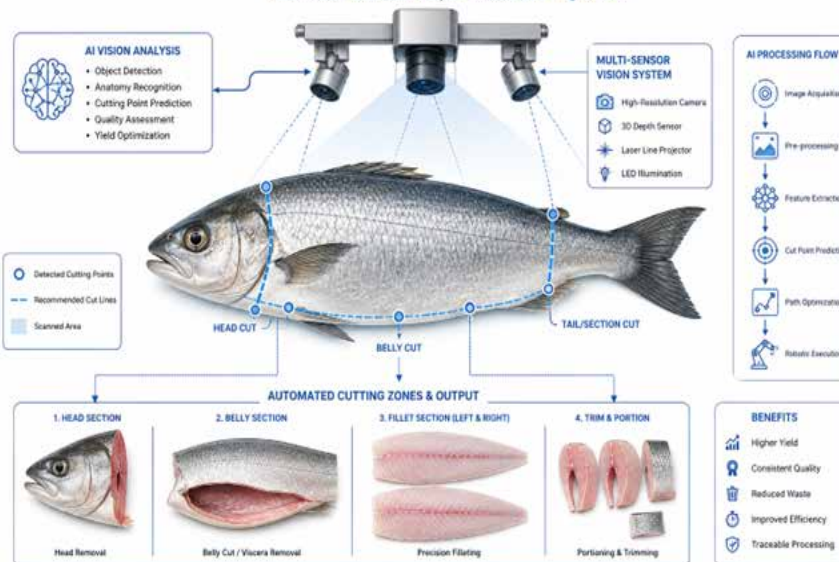


Figure 3: Precision cutting

## AI-BASED SEAFOOD TRACEABILITY AND SMART PACKAGING

AI and smart technology ensure transparency, quality, and safety across the seafood supply chain



Figure 4: Smart packaging and traceability

and InceptionV3) combined with classical ML classifiers on 4,476 fish body images. The SqueezeNet + SVM and SqueezeNet + ANN combinations achieved 100% accuracy in distinguishing fresh from stale fish outperforming previous benchmarks of 98%. These models leverage skin colouration, texture changes, and gill/eye appearance as key indicators.

Complementing image-based approaches, Kumaravel et al. (2025) introduced a low-cost paper-based pH sensor using Methyl Red and Bromocresol Purple indicators. Colour changes ( $L^*$ ,  $a^*$ ,  $b^*$  values) were fed into a Random Forest regression model to predict pH shifts caused by TVB-N accumulation. Excellent performance was recorded for Pomfret (MSE = 0.004625) and Mackerel (MSE = 0.005034), demonstrating reliable cold-chain monitoring across six seafood varieties under vacuum, shrink, and normal packaging.

These systems enable non-destructive, real-time assessment suitable for markets, landing centres,

## THE ROLE OF AI IN SEAFOOD PROCESSING

AI enables intelligent, efficient, and traceable seafood processing from catch to consumer

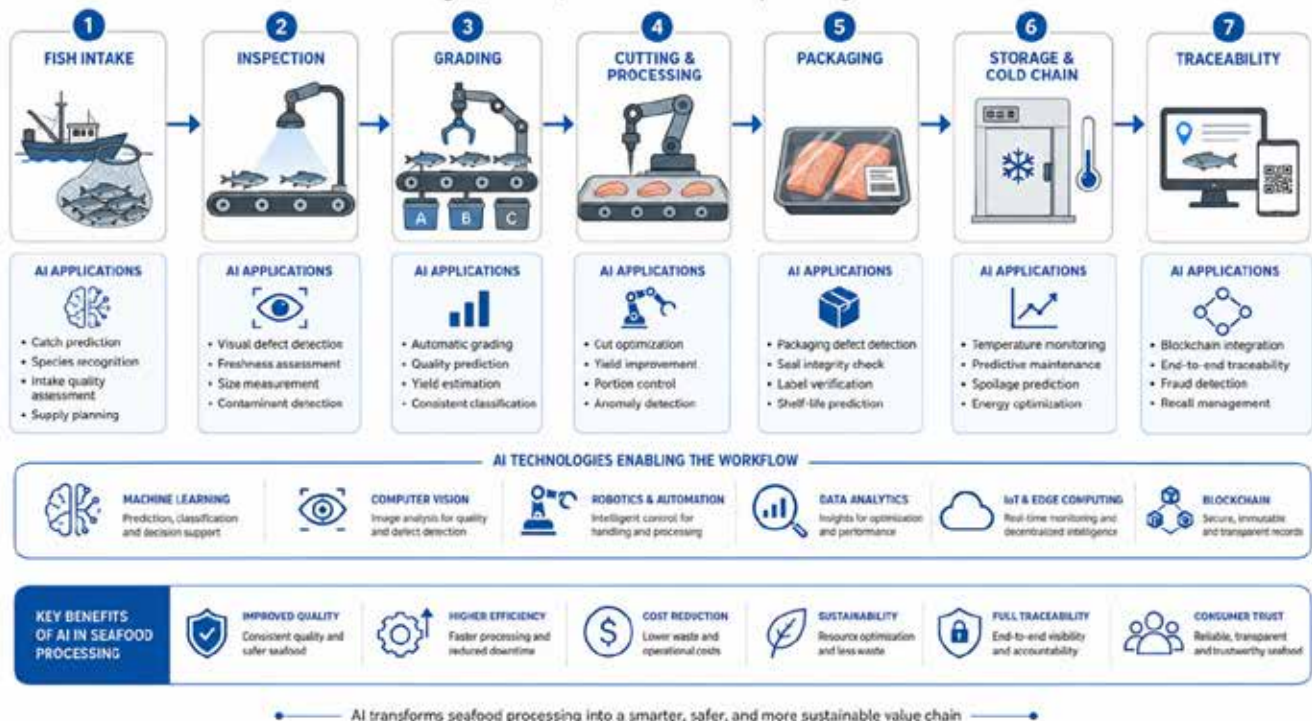


Figure 5: AI workflow in seafood processing

and processing plants.

### 3. Deep Learning Architectures for Quality Grading

Beyond binary fresh/stale classification, multi-grade quality assessment is essential for commercial valuation. Jayasundara et al. (2023) proposed two novel architectures: **FishNET-S** (VGG-16 with Block Attention Module) and **FishNET-T** (colour decomposition-based).

FishNET-S focused on the eye region of small fish like Indian Sardinella, achieving 84.1% accuracy by directing attention to diagnostically rich areas. FishNET-T targeted flesh colour of large species like Yellowfin Tuna, reaching 68.3% accuracy. Both used smartphone-captured RGB images, making the technology highly accessible for field use in resource-limited settings.

### 4. Machine Vision and Precision Automation in Processing

Azarmdel et al. (2025) developed an intelligent customer-operated fish processing system capable of handling multiple species. Using backlit blue background imaging and Automatic Colour Enhancement (ACE), the system classified four high-consumption fish (Silver Carp, Carp, Trout, Tigertooth Croaker) with exceptional accuracy:

- ANN (6-23-4 architecture): 99.62% training accuracy
- SVM: 99.69% training / 98.75% test accuracy

Once classified, species-specific algorithms determined head and belly cutting points with 96.6–99.5% accuracy. This represents a major step toward fully automated, multi-species processing lines that reduce labour, improve hygiene, and minimise yield loss.

### 5. Industry 4.0 Integration: Towards Smart Seafood Supply Chains

Subash et al. (2024) conducted a systematic literature review highlighting how Industry 4.0 technologies AI, IoT, robotics, blockchain, and computer vision - are converging in seafood processing.

Key benefits include:

- Real-time cold-chain monitoring
- Waste reduction through optimised cutting and grading
- Enhanced traceability reducing illegal, unreported, and unregulated (IUU) fishing
- Shift in workforce roles from manual labour to technology operation and maintenance

Integration of AI with robotics enables “smart” filleting, gutting, and packaging systems that maintain high yield while ensuring consistent quality.

### 6. Challenges and Future Directions

Despite impressive results, challenges remain: limited multi-species and multi-region datasets, environmental variability (lighting, moisture), computational requirements for edge deployment, and the need for explainable AI for regulatory acceptance. Workforce reskilling is essential to manage the transition.

Future research should focus on multimodal systems (image + sensor + e-nose), transfer learning for rapid adaptation to new species, edge-AI deployment on low-cost hardware, and blockchain-integrated traceability platforms. In the Indian context, affordable AI tools tailored for Indian Major Carps and shrimp can significantly boost farmer and processor incomes while reducing losses.

### Conclusion

Artificial Intelligence is no longer a futuristic concept in seafood processing, it is a practical, high-impact technology delivering superior accuracy in freshness detection, quality grading, and automation. By synthesising computer vision, deep learning, and smart sensors, the industry can minimise waste, enhance food safety, and improve sustainability. For countries like India, widespread adoption of these technologies in small and medium processing units could transform the sector. Collaborative efforts

between researchers, industry, and policymakers are needed to scale these innovations and build a more resilient blue economy.

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# Deep-Sea Fish Wastes: A New Frontier for Nutraceutical Development in India

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**Highlights:** India's deep-sea fisheries generate substantial quantities of processing waste, such as heads, skin, bones, scales, and viscera, which are often discarded or underutilized. Recent advances in marine biotechnology have revealed that these by-products are rich sources of bioactive peptides possessing antioxidant, antimicrobial, antihypertensive, and immunomodulatory properties. Extracting and utilizing these compounds offers promising opportunities for developing nutraceuticals, functional foods, pharmaceuticals, and aquafeed supplements. Along the southern coast of Kanyakumari District, the growing exploitation of deep-sea and mesopelagic fish presents significant

scope for converting fishery waste into high-value commercial products. This article highlights the potential of deep-sea fish waste valorisation as an emerging component of India's blue bioeconomy and sustainable fisheries development.

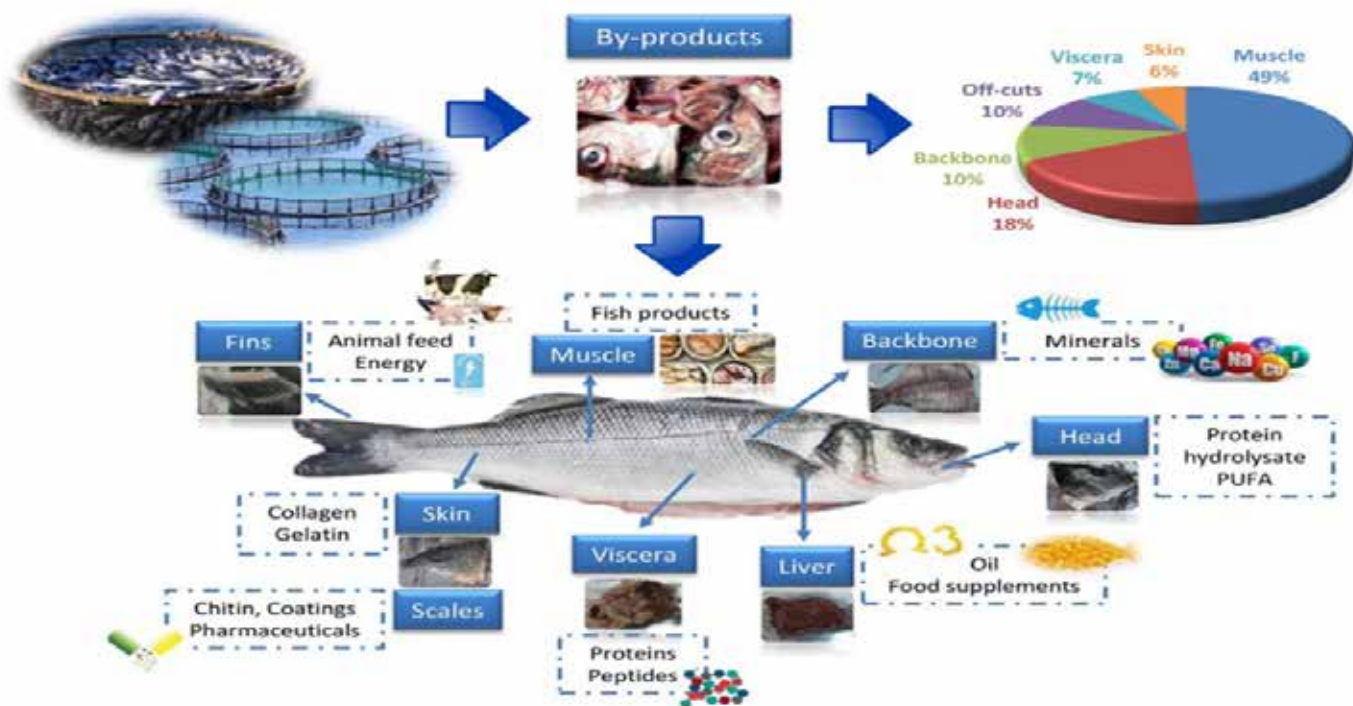
**Introduction:**

The marine resources of the southern coast of Kanyakumari district possess enormous untapped potential for the development of high-value marine nutraceuticals and functional bio-products. Among these, the derivation of bioactive peptides from deep-sea fish processing wastes has emerged as a highly promising field with significant applications in human health, food technology, pharmaceuticals, cosmetics, and aquaculture. In

recent years, growing concerns over fish waste disposal, environmental pollution, and sustainable utilization of marine resources have encouraged researchers and industries to convert fishery by-products into valuable commercial products. Deep-sea fishes and mesopelagic resources available along the Cape Comorin coast provide an excellent raw material base for such value addition initiatives.

**Fish Processing Wastes as a Valuable Marine Resource:**

Fish processing industries worldwide generate enormous quantities of waste during cleaning, filleting, canning, and export operations. Nearly 55–65 percent of the total fish biomass is discarded as waste in the form of heads, skin, bones, scales, viscera, fins, frames, and muscle





trimmings. Traditionally, much of this material has been disposed of or converted into low-value fishmeal and fertilizers. However, scientific investigations have demonstrated that these by-products are rich sources of proteins, collagen, gelatin, minerals, lipids, and biologically active compounds. Through modern biotechnological approaches, especially enzymatic hydrolysis, these proteins can be converted into small peptide molecules possessing several beneficial physiological activities.

### Deep-Sea and Mesopelagic Fish Resources for Peptide Production:

Deep-sea fishes such as lanternfishes (myctophids), ribbonfish, tuna processing wastes, mesopelagic fishes, shark skin, and other underutilized marine species are particularly rich in high-quality proteins suitable for peptide production. The Indian Exclusive Economic Zone contains vast mesopelagic fish resources that remain largely unexplored for nutraceutical and pharmaceutical applications. The utilization of these resources not only improves resource efficiency but also contributes to sustainable fisheries development and marine waste management.

### Production Process of Bioactive Peptides from Fish Wastes:

The production of bioactive peptides from fish wastes generally

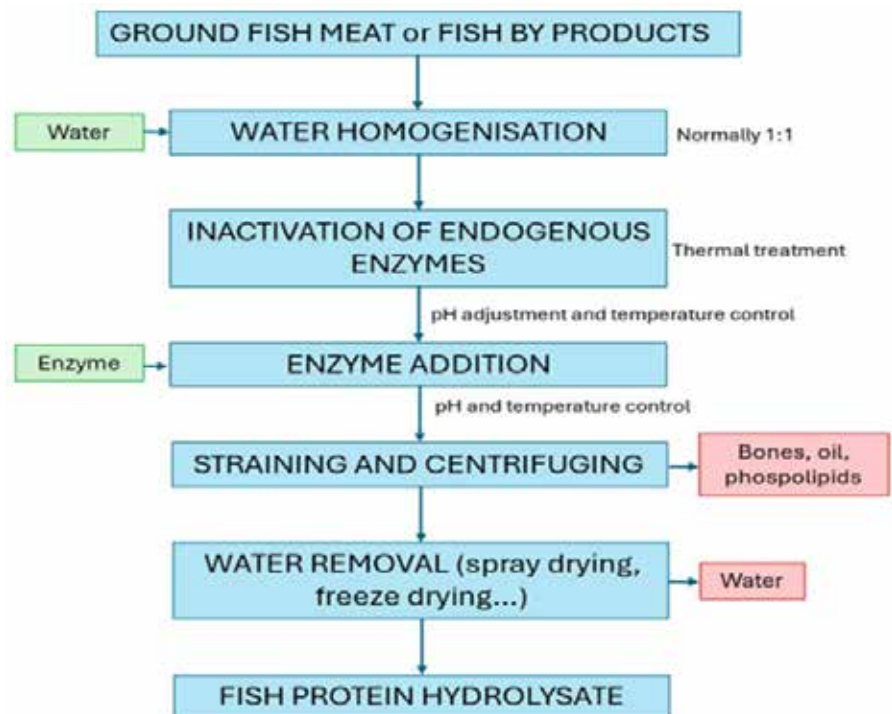
involves several carefully controlled processing steps. Initially, the collected fish wastes are washed thoroughly to remove impurities, blood, and excess fat. The materials are then minced and homogenized to facilitate protein extraction. Proteins are extracted using water or mild acidic and alkaline solutions under controlled conditions. Following extraction, enzymatic hydrolysis is carried out using commercial proteolytic enzymes such as Alcalase, Pepsin, Trypsin, Papain, or Flavourzyme. During hydrolysis,

complex proteins are broken down into smaller peptide fragments and amino acids. The efficiency of hydrolysis depends on parameters such as temperature, pH, enzyme concentration, and duration of treatment. Most hydrolysis reactions are performed at temperatures ranging from 45°C to 60°C and pH levels between 6.5 and 8.

The enzymatic process is highly preferred because it produces peptides with desirable functional and biological properties while preserving nutritional quality. After hydrolysis, the enzyme activity is terminated through heat treatment. The hydrolysate is then filtered and centrifuged to remove insoluble residues. Advanced purification techniques such as ultrafiltration are subsequently employed to separate low molecular weight peptides, particularly fractions below 3 kDa or 5 kDa, which are often associated with stronger bioactivities. Finally, the purified peptide solution is converted into stable commercial powder using freeze-drying or spray-drying technologies.

### Biological and Health Benefits of Marine Bioactive Peptides:

Bioactive peptides derived from marine fish wastes have attracted





considerable attention because of their diverse health-promoting properties. Several studies have reported antioxidant activities that help reduce oxidative stress in the human body. Certain peptides exhibit antihypertensive effects through inhibition of Angiotensin-Converting Enzyme (ACE), thereby contributing to blood pressure regulation. Other peptides demonstrate anti-inflammatory, antimicrobial, immunomodulatory, anti-diabetic, neuroprotective, and anti-aging properties. These health benefits have encouraged the incorporation of marine peptides into functional foods, nutraceutical beverages, dietary supplements, protein powders, and clinical nutrition formulations.

**Commercial Applications of Fish-Derived Bioactive Peptides:**

The commercial applications of fish-derived peptides are expanding rapidly across multiple industries. In the nutraceutical sector, peptide powders and collagen hydrolysates are marketed for improving skin health, joint function, muscle recovery, and overall wellness. The pharmaceutical industry is exploring marine peptides for the development of antimicrobial agents, wound healing products, anti-inflammatory

compounds, and cardiovascular therapeutics. In the cosmeceutical field, fish collagen peptides have become important ingredients in anti-aging creams, skin regeneration products, and hair and nail supplements due to their excellent biocompatibility and bioactivity.

Marine bioactive peptides also play an important role in aquaculture and animal nutrition. Fish protein hydrolysates are widely utilized as feed ingredients because they improve digestibility, growth performance, immune response, and disease resistance in cultured aquatic species. Additionally, certain peptides possess antimicrobial and antioxidant properties that can enhance food preservation and extend the shelf life of seafood products.

**Scope and Opportunities in Kanniyakumari District:**

The scope for establishing marine peptide extraction and bioprocessing industries in Kanniyakumari District is highly promising. The district possesses rich marine biodiversity, active deep-sea fishing operations, seafood processing facilities, and skilled coastal fishing communities.

Fishing harbours and fish landing centers along the Cape Comorin coast provide a continuous supply of raw materials for value-added processing. The establishment of peptide production units can significantly reduce fish waste pollution while generating additional income opportunities for fishermen, processors, and coastal entrepreneurs.

The development of marine peptide industries can further contribute to employment generation, export-oriented nutraceutical production, and sustainable blue economy initiatives in the region. With appropriate investment in research, processing infrastructure, and technology transfer, Kanniyakumari District can emerge as an important regional hub for marine bioactive compounds and value-added fisheries products.

**Conclusion:**

In conclusion, deep-sea fish processing wastes represent an underutilized yet highly valuable marine bio resource with immense potential for commercial exploitation. Through enzymatic hydrolysis and advanced purification technologies, these wastes can be transformed into bioactive peptides possessing important nutritional, pharmaceutical, cosmetic, and industrial applications. The conversion of fish waste into wealth not only supports environmental sustainability but also strengthens the economic prospects of coastal communities. For regions such as Kanniyakumari District, marine peptide production offers a promising pathway toward sustainable fisheries utilization, industrial innovation, and blue economy development.



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