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Enhancing Feed Digestibility in Finfish

Scaling Methane-based Protein for Aquafeeds

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A tilapia pond with hapas for prestocking monitoring at Arnan Farm, Thailand, p 50

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Zuridah Merican

The Tilapia Journey continues

Tilapia has often been referred to as St. Peter's fish in historical contexts but in more recent times, it has had a transformational journey. Prior to the 1980s, tilapia was a backyard species grown in neighbourhood polyculture farms for the community and sold in the local markets in Africa, China and Southeast Asia. Average sizes were small, limited to 200-350g, mainly due to the culture period and hence cash flow for the farmer but also competitively priced to match the purchasing power of the mass population. One could refer to this as Phase One of the tilapia journey. Today, tilapia is cultured in more continents than any other fish species.

However, during phase one, traditional tilapia strains had poor growth rates, inconsistent performance, and limited seed supply. This prompted the GIFT strain which was first developed in 1988 by WorldFish (then ICLARM) in collaboration with partners from the Philippines and Norway. It was created by selectively breeding Nile tilapia (*Oreochromis niloticus*) for faster growth and better performance. This catalysed Phase Two when GIFT tilapia was distributed globally and adopted by at least 17 governments because it gave higher yields making it the preferred freshwater fish for commercial farming and food security.

In Asia, Phase Three started when Regal Springs Indonesia (RSI) turned tilapia into an export commodity. The company started tilapia culture in cages in reservoirs in Java and later in Lake Toba, Sumatra. This was a revolution of sorts as tilapia cultured in lakes do not have the off-flavour or muddy taste - a negative perception normally associated with pond-cultured tilapia. It is interesting to note that the off-favour was a no-no for the North American consumer who wanted fillets which mimicked sea-caught groundfish. Processing of Horeca-size fillet above 160g requires the harvest size of more than one kg fish since filleting percentage skin-off results in only 39% of the whole fish. Consequently, this created a problem and opportunity, monetising the remaining 61% of the fish.

From a business model perspective, the opportunity is for the co-product matrix. The belly forms the ingredient for Tilapia Belly Kabayaki, a delicacy in Taiwan. The skin can be salted and dried for food crackers or an excellent source of collagen while the scales are a good raw material for gelatine. Both collagen and gelatine are sought after by the pharmaceutical and beauty industries. The frames and offal can be turned into fishmeal as a feed ingredient.

Phase Four is unfolding as we speak. The years 2026/2027 are anticipating lower quotas for groundfish like cod and haddock, traditional for the British Fish & Chip staple. Prices are increasing faster than inflation in the UK and there is concern that this may soon be out of reach for the common man. Tilapia is an option - its loins (upper portion of the fillet without the central blood line) which is thicker but must come from a 1.5kg fish. This requires both good genetics and high-density feed to match the growth.

What about Phase Five? At the recent World Aquaculture 2026 Singapore in June, the session on Singapore aquaculture started with the problem statement. Singapore's wish list includes a profitable and sustainable aquaculture industry, food security and optimising the use of its coastal waters. Conversely, it is constrained by land scarcity, a high cost of production, biosecurity and disease and it lacks economies of scale. The marine tilapia (mainly Oreochromis hybrids) meets most of the criteria and avoids many of the constraints. It lacks the muddy taste, optimises the use of coastal waters and has a lower cost of production compared to other marine species (for food security). The fillet is the 'cash cow' which can serve Government funded institutions viz. hospitals, armed forces and national service. The co-products of belly, skin and scales provide higher margins for a profitable aquaculture.

This editorial is convinced that the tilapia industry will not stop at Phase Five but AAP is currently unable to forecast the sixth.



If you have any comments, please email: zuridah@aquaasiapac.com

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In Singapore: Collaborative approach to advance aquaculture



Dr Janil Puthucheary, Senior Minister of State for Sustainability and the Environment (centre) at the exchange of documents between Singapore Food Agency (SFA) and the Singapore Institute of Technology (SIT) to establish the Feed and Feed Ingredient Technology Centre (F2TC), at World Aquaculture 2026 on 3 June 2026. Photo credit: Singapore Institute of Technology.

In June, Dr Janil Puthucheary, Senior Minister of State for Sustainability and the Environment, opened World Aquaculture 2026, the second edition held in the city-state after the 2022 event. In his welcome address, reflecting the event theme *"High Yield Production through Nutrition, Health, Genetics and Resources,"* he emphasised that high-yield, input-driven productivity is essential for building a resilient aquaculture sector prepared for future challenges.

Singapore is committed to advancing innovation in aquaculture through a science-led, collaborative approach with industry and research partners. The country's aquaculture strategy is anchored on three input pillars.

In species and genetics, the National Broodstock Centre and the Hatchery Development and Recognition Programme (HDRP) focus on Asian seabass, marine tilapia and red snapper — species with strong domestic and regional demand. Selectively bred seabass now grows 30% faster.

In nutrition and health, Singapore has positioned itself as a regional base. During the event, the minister witnessed the signing of a collaborative agreement between the Singapore Food Agency (SFA) and the Singapore Institute of Technology (SIT) to establish the Feed and Feed Ingredient Technology Centre (F2TC).



Ronnie Tan, Regional Aquaculture Consultant, USGBC, Malaysia (left), with from the right, Jiang Junhui, Director, Aquaculture Technology Dept, Singapore Food Agency; Yeo Keng Joon (Singapore); Leong Der Yao, Deputy Chief Executive Officer, Singapore Food Agency.

This centre will drive innovation, strengthen Singapore's leadership in warm-water aquafeed, and anchor high-value activities locally. Partners include Clextral, for feed extrusion capability and INVE, for translating R&D into commercially relevant aquaculture solutions.

In technology, several farms are already improving operational stability and output consistency. A demonstration project using automated vaccination machines for Asian seabass, marine tilapia and red snapper aims to improve disease resilience and reduce manual labour. Once validated, farms may adopt these technologies with co-funding from SFA's Agri-food Cluster Transformation Fund 2.

The Singapore Story

A special session, the AquaTropics Forum, organised by AquaPolis — the national aquaculture R&D and innovation programme under SFA — highlighted Singapore's aquaculture research, technology development and translational efforts towards sustainable food production.

Ronnie Tan, Regional Aquaculture Consultant, US Grains and Bioproducts Council (Malaysia), discussed strategic models for growth, value chain analysis and product diversification in his presentation "Aquaculture Business Models for Singapore Inc." These models consider Singapore's strategic goals for sustainable, profitable aquaculture to enhance food security and optimise coastal waters, while addressing constraints such as land scarcity, high production costs and limited economies of scale.

Tan noted that Singapore should leverage its strengths — world-class infrastructure, investment capability, scientific expertise and regional logistics — to become the leading global industrial partner in the barramundi ecosystem. He proposed enterprise development under "Barramundi Solutions & Services" through Enterprise Singapore. Marine tilapia, which lacks the muddy taste associated with freshwater tilapia, optimises the use of coastal waters and has a lower cost of production, making it an ideal species for food security.



Uni-President Vietnam's Malaysian team, from right, Kuek Sian Chai, Director, Aquafeed Business Division, Ng Han Boon and Ee Twan Siong. On second left is Dr Lay Nguyen, Biomar, Vietnam.



The OTT-In Situ team, from right, Alex Hing, Regional Sales Manager; Faizal Yusoff, Sales & Service Manager, Corentin Leclerc, Regional Sales Manager -FEA and visitor, Bryce Lim, ANSAC Technology.

Tan proposed two models:

- An integrated ASEAN regional production model to achieve economies of scale for the Asian seabass.
- A hybrid marine tilapia model to monetise 100% of the fish, balancing profit and social responsibility. The co-product matrix positions the commodity fillet as the "cash cow" for food security, while premium Kabayaki belly, collagen and gelatine, and fishmeal provide additional high-margin products

Highlights on industry-led innovations

John Diener, CEO of Vertical Oceans, described the company's AI-driven, stacked, 100% recirculating (RAS) multiphase farming system for vannamei shrimp in full seawater. The system is biosecurity-by-design and algorithm-controlled from day one, said Diener. Its Intelligent Habitat (iHAB) is a fully autonomous, self-contained ecosystem that balances water quality, microbiology and feeding. The system uses metagenomics to analyse the microbial blueprint.

An example of urban, climate-controlled aquaculture is Singapore's first high-tech, land-based rainbow trout indoor farm by Blue Aqua International. CEO Dr Farshad Shishehchian described the facility — comprising hatchery, nursery and modular tank systems of 28m diameter — designed to produce 1,000 tonnes of 500g fish. A chiller plant optimises temperature for the cold-water trout.

Singapore Aquaculture Technologies (SAT), a pioneer in floating-tank fish farms, operates data- and AI-driven RAS. Dr Michael Voigtmann, CTO/COO, discussed advances in microbiome surveillance for RAS, noting that microbial communities vary across system components. On-farm metagenomic sequencing can provide same-day or near-real-time insights into microbial diversity, enabling farm-level analysis and action. The key is not only identifying what is present but also tracking how abundance changes over time.

Dr Olivier Decamp, INVE Aquaculture, emphasised that early nutrition, though a small proportion of total production cost, can strongly influence final performance. Nutrition in the first 15–20 days for shrimp and 30–40 days for fish helps shape robustness and growth potential, alongside genetics. INVE validates R&D and partner-developed protocols with farmers, SFA and local sites to adapt them for its products. Improved broodstock nutrition can also produce stronger fry with better growth and stress robustness.

Flagship aquaculture research initiative

The first AquaPolis R&D tranche of SGD 18.5 million (USD 14 million) focuses on optimising Asian seabass research and production in Singapore. This three-year initiative unites researchers, industry partners and fish farms to advance local aquaculture through science-driven innovation and collaboration.

Programme Co-Lead Dr Richard Le Boucher at Temasek Life Sciences Laboratory described the work, which brings together 18 research groups across eight Higher Learning and Research Institutes, 19 industry partners and more than 40 coordinated trials structured across eight integrated work packages (aqp.sg/asian-seabass/). The programme addresses three major production bottlenecks identified by local producers:

- improving fingerling quality and robustness
- reducing disease-related mortality during grow-out
- enhancing the nutritional value and market differentiation of locally farmed seabass relative to imports

The minister announced an additional tranche of SGD 6.3 million (USD 5 million) in R&D funding to AquaPolis to enhance marine tilapia aquaculture in Singapore. This brings total R&D funding for the AquaPolis Programme to close to SGD 25 million (USD19 million).

Research-led innovations

Under Singapore Food Story 1.0, A*STAR Infectious Diseases Labs evaluated epitope-based vaccine strategies against scale drop disease virus (SDDV), which causes severe outbreaks and 40–70% mortality in Asian seabass. Following a controlled challenge study, Professor Laurent Renia noted that the SFS 2.0 programme is now developing multi-epitope and modular vaccine constructs.

High-density recirculating aquaculture systems (RAS) present a persistent challenge: clinically relevant stress and disease signals often remain hidden until pathology is visible. Associate Professor Michael Kasper of Fraunhofer Singapore Research Centre is developing a multimodal early-warning framework designed to close this gap.



At the home-grown Forte Biotech, from left, Micheal Nguyen, Co-founder with visitors, Mecha Girish (Kenya) and Benedict Tan, Programme Director, Hatch Blue, Singapore. Forte Biotech develops rapid, portable, on-site diagnostic test kits for major shrimp pathogens. Hatch Blue is a global accelerator, venture capital investor, consultancy, and ecosystem builder focused entirely on aquaculture and alternative seafood. Singapore is one of the accelerator's main hubs.

Beyond replacement: Why marine ingredient scarcity is reshaping the future of aquaculture



French insect meal scaleup **Innovafeed** released a white paper "**Beyond replacement**" which noted that over the past months, the aquaculture industry has entered a new phase, marked by tightening supplies of marine ingredients, record fishmeal and fish oil prices, and growing pressure on global feed value chains. Rather than asking "How do we replace fishmeal?", the paper explores a broader question: how can the industry build more resilient, functional and sustainable feed strategies?

For decades, aquaculture has relied on fishmeal and fish oil as its nutritional foundation. Today, that model is under increasing pressure. Several indicators point to a structural shift. The question is no longer whether shortages will occur, but how the industry can adapt. Historically, alternative proteins were developed to replace fishmeal.

Authors, Roel Boersma, Product Strategy and Marketing Director and Maye Walraven, Chief Business and Impact Officer at Innovafeed noted that, "Since May 2026, the sector has been living through the most severe fishmeal crisis on record. Supply of marine meals has been broadly flat at 5.5-6 million tonnes for years, while the high-value aquaculture segment most dependent on it keeps growing at around 3% a year. The cost base of the fishery itself is rising too: fuel, labour, tightening regulation and the steady expansion of protected areas all lift the real cost of landing wild fish, and those costs do not fall back when a season improves."

They added, "By mid-2026, super prime fishmeal was trading around USD 4,000 a tonne, against a commodity benchmark of roughly USD 2,100-2,400 and premium omega3 fish oil was approaching USD 7,000. For aquafeeds, the challenge is different. The question is no longer whether shortages will occur, but how the industry can adapt."

Ingredient replacement to ingredient optimisation

The objective is no longer simply to substitute marine ingredients, but to use them where they deliver the highest biological value while complementing them with functional ingredients that improve animal performance, resilience and supply security. This represents a shift from ingredient replacement to ingredient optimisation. Marine ingredient scarcity is becoming structural, not cyclical scarcity changes the role of alternative ingredients. Functional ingredients are becoming strategic assets.

Innovafeed believes that the next generation of aquafeeds will combine several complementary ingredients rather than rely on a single substitute. Hilucia™ Black Soldier Fly Larvae (BSFL) ingredients naturally provide: Highly Digestible Protein Lauric Acid Antimicrobial Peptides Chitin Functional Lipids. These compounds contribute not only to nutrition but also to gut health, immune support and animal robustness.

A shared challenge, and a narrowing window

The scale of the task is real. The Nature Food modelling suggests that simply holding 2022 output steady, under a combined scenario of tighter management and climate impacts, would call for roughly 1.8 million tonnes of alternative ingredients every year. That figure is both the measure of the challenge and the size of the opportunity for ingredients that can credibly fill the space.

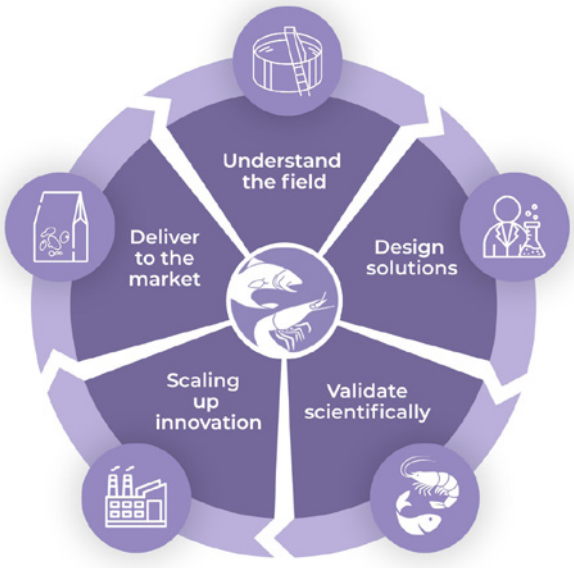
Innovafeed offers this perspective not as a large incumbent supplier at 6,000 tonnes a year. It is only a contributor among many but as a partner working alongside formulators on a problem the whole sector share. It calls for building a resilient ingredient basket together, so that the current crisis is resolved and the next one is prepared for. The window to act from a position of strength is narrow.

Those who secure functional, decoupled supply and forge these partnerships now will help shape the next decade of aquaculture nutrition; those who wait will be left competing for what remains, at prices set by the shortage. Scarcity has already decided that the industry will move beyond marine dependency. The open question is who leads the transition, and who is left to follow.
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My View: When genetics listen to the farmers

Why field intelligence must guide the next phase of shrimp breeding

By Balasubramaniam



Shrimp harvested from Certitude Farms in Tamil Nadu Photo credit: Balasubramaniam V.

Genetics cannot be designed only in laboratories. It must be guided by field intelligence from farms." This is a thought that has been on my mind, ever since I first listened to geneticists speak at an Aqua India conference in 2018 in Chennai.

The scientific discussion on genetics was impressive and highly advanced. But it also made me think about how those ideas can connect with the daily experiences of farmers. Over the past year, my work with farmers and scientists through the Collaborative Shrimp Disease Investigation Program (CoSDIP) has reinforced that belief.

CoSDIP began as a farmer-led effort to better understand some of the disease situations emerging in shrimp farms. Farmers, scientists and industry partners come together to discuss and investigate. Farms are being monitored, samples are being collected and laboratories are analysing what we are seeing in the field. Recently, Oscar Henning, a geneticist working with Centre of Aquaculture Technologies (CAT), pointed out that such programs could provide valuable information for training researchers in genomic selection — linking DNA profiles with shrimp that perform well under real farm conditions.

"I believe that this is exactly where the future of shrimp genetics must go — closer to the farm."



Balasubramaniam V is owner of the 60-acre (24ha) Certitude Farms in Tamil Nadu and Secretary of the Prawn Farmers Federation of India (PFFI).

The farm is not a laboratory

Shrimp farming happens in a complex biological environment. No two ponds are the same. Water sources differ. Pond age differs. Organic loads accumulate over time. Microbial populations change continuously. Weather patterns shift. Management practices vary.

Anyone who has spent time in shrimp farming understands this. In response to my earlier LinkedIn post on CoSDIP, Madhu Mohan Talluri, a core CoSDIP team member, made this observation: he pointed out that microbial consortium and environmental factors in shrimp ponds can vary significantly across regions in India. These variations influence pond ecology, shrimp health and overall production performance. Without close monitoring of real-time culture practices in farms, it is difficult to generate the reliable data needed to guide genetic improvement programs or to select strains suited for local conditions.

Bridging the gap

The farm itself becomes a critical source of knowledge. Bridging the gap –between farms and breeding programs, geneticists today have access to powerful tools. Genomic technologies and structured breeding programs have significantly improved shrimp aquaculture over the past two decades. However, there has always been a natural gap between breeding environments and grow-out farms. Breeding programs operate under controlled conditions designed to measure specific traits accurately.

Farms, however, operate in open systems where environmental factors, microbial dynamics and pathogen exposures interact continuously. Programs like CoSDIP can help bridge that gap. While the primary objective of CoSDIP is disease investigation, along the way, the program has also generated structured field intelligence.

Over time, data from real farming conditions and real environmental variability can help scientists and breeding programs better understand how shrimp perform under the environments where they are grown.

Importance of genetic diversity

At our meetings, the topic on maintaining diversity within breeding populations was discussed. Dr Rajkumar Singh, one of our field coordinators involved in the investigation, expressed this concern very clearly. He said, "Diversity in the genetic pool from where lines are developed must be the norm and not a choice. Depending on only a few lines can lead to catastrophic results sooner than later." His comment reflected something agriculture has learned repeatedly across sectors — narrowing the genetic base increases vulnerability.

Ensuring sufficient diversity in breeding programs therefore is essential for the long-term resilience of the shrimp farming sector.

Management helps, but it cannot do everything

Shrimp farmers invest heavily in farm management. Pond preparation, liming, aeration, feed management, water quality control and biosecurity practices are now routine across much of the industry. Clean post larvae and good management practices remain the foundation of shrimp farming. However, experience across farming regions also shows that some disease challenges cannot be solved through management alone.

In terrestrial livestock and fish farming, vaccines play a key role in disease control. In shrimp farming, however, practical vaccination systems are not currently available. Once disease enters a pond, curative options remain extremely limited. That reality makes genetics even more important. Shrimp that can tolerate environmental stress will be able to withstand pathogen exposure or continue performing under moderate disease pressure, and hence make a significant difference to crop stability.

Listening more carefully to the farmers

These reflections have also impacted on another new research area - the possibility of developing genetically improved pathogen-tolerant lines of the indigenous shrimp *Penaeus indicus*. The idea is still evolving, but the objective is clear. It is not simply to create another breeding effort, but to think carefully on its breeding direction –it should be guided by real farming conditions.

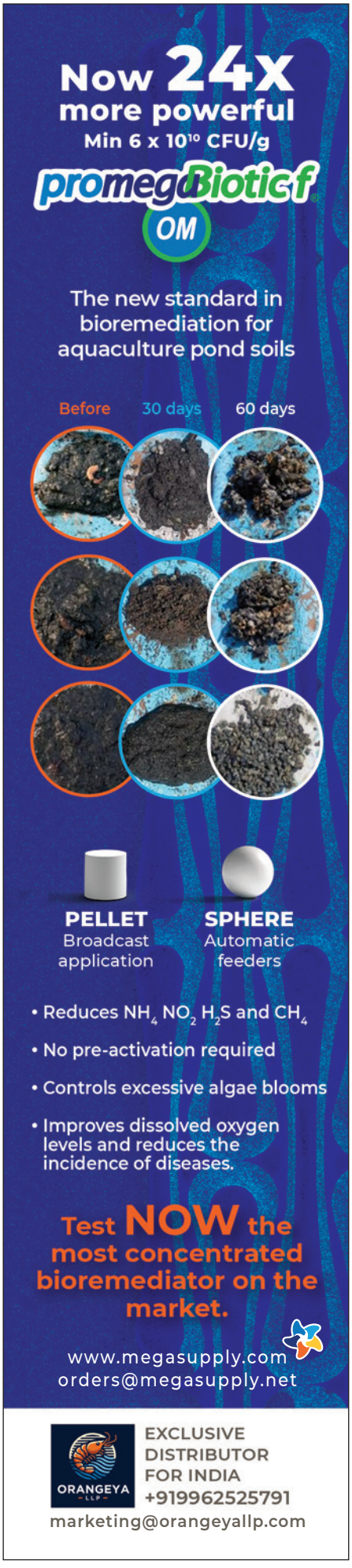
Historically, most of the feedback guiding genetic improvement programs has naturally come from the hatchery sector. Hatcheries play an essential role in the industry and have contributed greatly to the development of shrimp aquaculture. Hatcheries and farms operate under quite different environments. The farm is where shrimp ultimately face the full complexity of environmental stress, microbial dynamics and pathogen exposure. That is where the true test of genetic performance takes place. As the industry evolves, we need stronger mechanisms that allow structured feedback from farms to flow back into breeding programs. We can help begin that process.

A shared responsibility

The future of shrimp breeding will neither be determined by genetics alone nor only by farm management. It will depend on continuous interaction between breeding companies, scientists and farmers. Breeding companies bring expertise in genetics and genomics. Scientists contribute analytical tools and research frameworks. Farmers contribute daily observations from the field.

When these perspectives come together, the industry gains something extremely valuable — a clearer understanding of how shrimp actually perform in the environments where they are grown. That brings us back to the thought that started this reflection.

"Genetics cannot be designed only in laboratories. It must ultimately be guided by field intelligence from farms."



Experiences in vannamei shrimp hatchery operations in India

Part 2 –Live feed production to larval rearing

By Surendran V, Ravikumar Y and Chandrasekhar JYR



From left, Indoor, intermediate and outdoor mass production of diatom Chaetoceros sp.

In some perspectives on *Penaeus vannamei* shrimp hatchery operations in India, published in May/June 2026, we discussed our experiences on broodstock management and farm performance at one of the many projects at Vaisakhi Marine Resources. This second part covers live feed production in hatchery operations, algal culture as well as *Artemia* hatching and larval rearing.

Algal culture

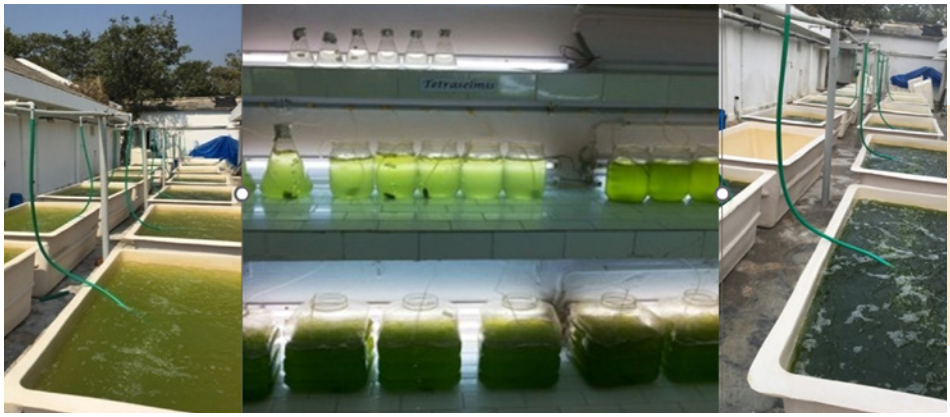
Most hatcheries in India have complete algal culture facilities both indoor and outdoor. A general practice is batch culture of a single microalgae species. It is either *Chaetoceros sp*. or *Thalassiosira sp*. Although there are different media available, such as TMRL or Walne's, most of the hatcheries use Guillard's F/2 and F/4 media. Very few hatcheries do batch culture of multiple algae. At the hatcheries operated by Vaisakhi Marine Resources, the main species cultured are *Thalassiosira* and *Chaetoceros*, used either singly or in combination. We also supplement with *Isochrysis*, *Nannochloropsis* and *Tetraselmis*.

Some challenges faced with algal culture include inconsistencies in quality and quantity in outdoor mass production and sometimes, indoor culture quality as well. An over-designed outdoor algal facility, with transparent roofing for protection against rain removes the constraints due to limited facilities and rainy seasons.

Artemia hatching

An innovative practice for the past few years has been the exclusive use of live and other forms of freshly produced *Artemia* products from outside exclusive suppliers. Suppliers provide fresh *Artemia* for several hatchery projects catering to their requirements.

The standard operational practices (SOP) on *Artemia* hatching and feeding include several successive steps; starting with the hydration of *Artemia* cysts, chlorination, as well as partial decapsulation, freshwater wash, incubation, *Artemia* nauplii harvest, freshwater wash, holding and feeding.



At the hatcheries operated by Vaisakhi Marine Resources, there are separate facilities for algal production. From left, outdoor production of Nannochloropsis spp and indoor production (centre) and outdoor mass production of Tetraselmis spp.

Larval rearing

We use standard operating practices (SOP) developed in-house; our hatchery is based on a modified Galveston system with isolated and modular facilities. Our SOPs include shutdown and disinfection after every production cycle and use of treated seawater followed by brisk stocking of nauplii. After *Enterocytozoon hepatopenaei* (EHP) became a major challenge in shrimp aquaculture, we added sodium hydroxide as the first step in the shutdown procedure, followed by chlorine and acid treatments, to prevent EHP contamination in the hatchery facility. We follow a multi-species algal feeding regime, optimising algal feeding densities and a well-developed water and feed management protocol.

Sea water management involves a standard treatment process which includes the following: chlorination of treated seawater, transfer and recirculation through slow and pressurised sand filters, followed by carbon and cartridge filters. Stocking nauplii begins after the total disinfection of larval tanks. Tanks are cleaned and dried before stocking nauplii. Nauplii are stocked in 0.5micron filtered seawater. Stocking density of nauplii is 150-200 nauplii/L.





Left: Preparation of larval rearing tank for stocking nauplii and below, larval rearing tanks during operations.

Larval rearing from nauplii (N6) to mysis 3 (M3) takes about 7 days before post larvae metamorphosis on day 8 (under optimum environmental conditions). Post larval age is denoted by the number of days after metamorphosis to post larvae; PL10 is 10 days old post larvae, after it had metamorphosed from mysis 3 to post larvae).

The water management schedule includes minimum water exchange during larval stages (zoea 1-3 and mysis 1-3), followed by moderate water exchange starting from post larval stages (i.e.30-50% water exchange per day or more) based on the larval rearing tank. Probiotics are used regularly during larval rearing. No antibiotics are used in hatchery operations.

Feeding protocols

Algal feeding (mostly diatoms) starts from first feeding to PL2, after which it is discontinued. Zoea are fed artificial feeds at around 0.5g/tonne/feed at 6 times/day and mysis are fed artificial feeds at 1.0g/tonne/feed at 6 times/day, whereas artificial feeds are fed to post larvae based on requirement (*ad libitum*), about 8 times/day. Frozen *Artemia* is fed from mysis onwards and live *Artemia* is fed during post larval stages until they are ready for distribution. Artificial microencapsulated diets and microparticulate diets are also fed during larval and post larval stages. Generally, PL10 to PL15 are sold to farmers.



Managing algae varieties in larval feeding

The main algae (*Chaetoceros* or *Thalassiosira*) are fed at 10% of larval rearing tank volume to meet algal feeding density of approximately 0.10 – 0.15 million cells/mL (*Chaetoceros*) in the larval rearing tank. Additional algae varieties (such as *Nannochloropsis*, *Isochrysis* and *Tetraselmis*) are fed only at 1% of larval rearing tank volume as supplementary feed.

Feeding with *Artemia*

This is described in Table 1.

Stage	*Artemia* feeding in a 10-tonne larval rearing tank - gram (x times/day)	*Artemia* nauplii/mL	*Artemia* nauplii / larva	Remarks
N6-Z3/M1				No *Artemia*
M2-M3	50 (2X)	1	5-15	Frozen *Artemia*
M3-PL1	50 (4X)	1	5-15	Live *Artemia*
PL1-PL12	50 (4X)	1	5-15	
PL13-PL18	25 (4X)	0.5	2.5-7.5	
Note: The consumption per million PL production is around a case of 12 cans, each can is 425g of *Artemia* cyst.				

Table 1. *Artemia* feeding programme at a hatchery operated by Vaisakhi Marine Resources.

Productivity and challenges during larval rearing

Our productivity hovers in the range of 60-120 larvae/L. The mean survival during larval rearing was 46% over 10 cycles in a year (Figure 1). Challenges in larval rearing include poor survival (albeit rare) of nauplii during long distance transportation, mortalities at the different larval stages (zoea, mysis, early PL and late PL stages) and zoea and mysis syndrome. The latter causes high or total mortality during these stages. Other challenges have been declines in seawater salinity during October to December and the rainy season affecting outdoor algal mass production.

Health and quality checks in hatchery operations		
Broodstock	**Eggs and nauplii**	**Post larval quality**
Size/age	Egg washing	Stress test
Health status - SPF - Surveillance for EHP and WSSV (broodstock and fresh feed)	Nauplii washing	PCR test for EHP WSSV

Table 2. Health and quality monitoring in hatchery operations.

"In biosecurity, we take extra steps to pasteurise live polychaetes and freshly collected oysters. Although this reduces the feed's nutritional value, it is essential to ensure biosecurity."

Health management and biosecurity during hatchery operations

We follow standard procedures on health management and biosecurity (Table 2). We implement distinctive health management steps such as egg and nauplii washing and a comprehensive HACCP approach to ensure health standards. By implementing rigorous quality controls at each stage of our process, we consistently achieve a high-quality final product.

In biosecurity, we take extra steps to pasteurise live polychaetes and freshly collected oysters. Although this reduces the feed's nutritional value, it is essential to ensure biosecurity. Additionally, in place is the regular disease surveillance programme for the broodstock which includes testing broodstock every fortnight for white spot syndrome virus (WSSV) and EHP.

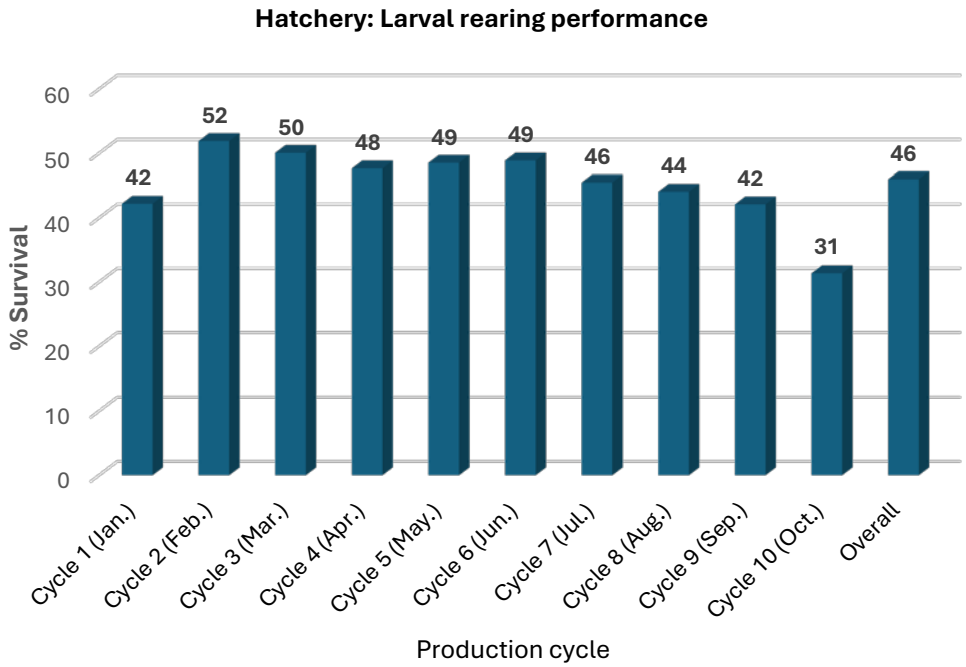


Figure1. Larval rearing performance in terms of % survival during each cycle in 2020-2022.

The above rigorous quality controls are in addition to standard biosecurity measures commonly practiced in Indian hatcheries; practices which include physical separation, hand washing, foot baths, tyre dips, dedicated operational teams, regulated staff movement, closed seawater reservoirs, peripheral drains, screens and effluent treatment plants (ETP).

Post larvae harvesting and transport

Post larvae are generally shipped in oxygenated polybags containing 1,000 to 5,000 PLs in 3–5L of water, with the temperature reduced to 22–25°C. Some farmers prefer to collect PLs in HDPE tanks at a density of 200,000 PLs per 200L.

Cost of PL production

Presently, in India, *P. vannamei* post larvae costs ~ 25 Indian paise or USD3/1000 PL. Table 3 itemises the cost components in 2024.

Cost inputs for post larvae production in 2024	Paise per PL	USD per 1,000PL
Nauplii	**5.00**	**0.60**
Feed		
Artemia	5.00	0.60
Other feeds	5.00	0.60
Probiotics	1.00	0.12
Chemicals	0.50	0.06
Consumables	0.25	0.03
Power and fuel	2.00	0.24
Salary	1.50	0.18
Repair and maintenance	0.25	0.03
Administrative expenses	1.50	0.18
Packing	1.00	0.12
Cost of sales	1.00	0.12
Incentives	1.00	0.12
Total	25.00	3.01

Table 3. Cost of production for *P. vannamei* post larvae (PL10-15) in India in 2024.

Market prices of post larvae

Figure 2 shows how *P. vannamei* post larvae prices (USD/1000PL) have changed over recent years: starting at approximately USD5 in 2009, rising to a peak of USD9.2 in 2014, and then dropping to about USD3.4 currently. Hatchery operators now face significant challenges, operating with very narrow profit margins of just 10–15%.

India's success with *P. vannamei*

The reasons for India's astonishing success in vannamei shrimp farming came from the availability of technology, well trained and experienced technical manpower, well developed hatchery infrastructure, regulations in place by the Government of India and the demand – supply gap favouring suppliers.



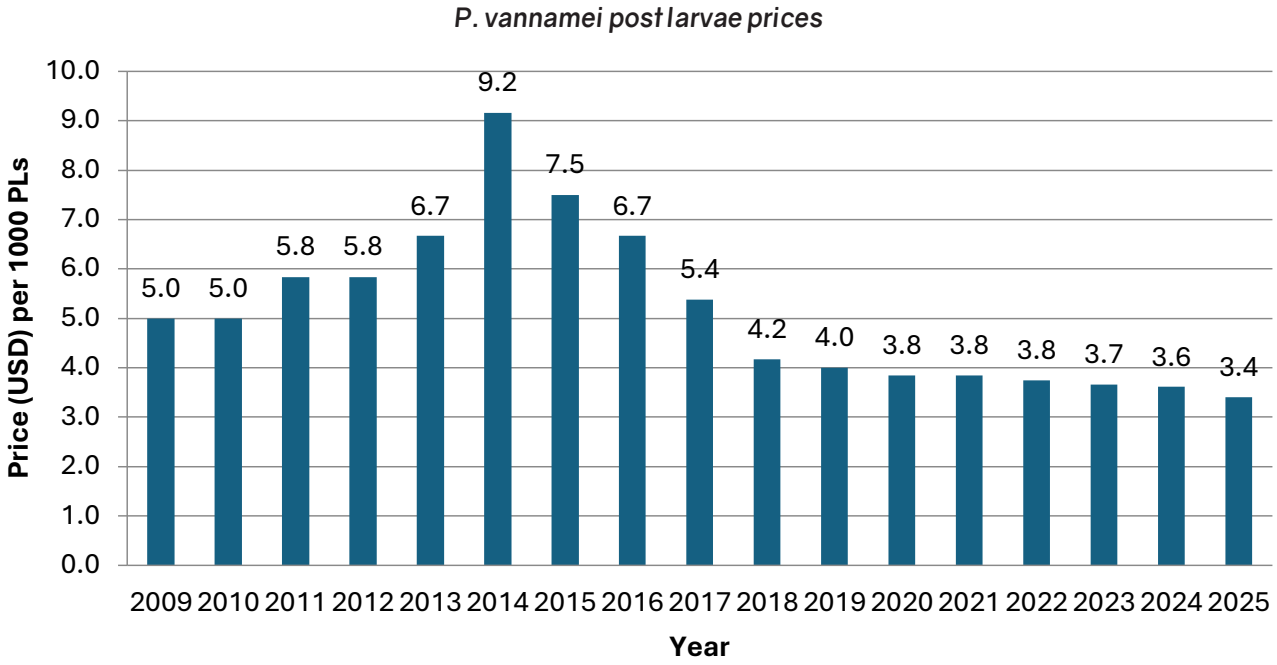


Figure 2. Trend in *P. vannamei* post larvae prices in India from 2009-2025.

The hatchery segment contributed to this success in the following ways:

Government oversight of broodstock control and regulation, supported by SPF broodstock, careful supplier selection, and quarantine, has strengthened hatchery development. Earlier technologies for indigenous species also played a role, including *Penaeus indicus* technology developed by the Central Marine Fisheries Research Institute (CMFRI), India, in the 1970s and *P. monodon* technology in the 1980s.

Early technologies and projects, including those listed below, helped standardise hatchery technology in India during its formative years.

- Conwy system technology from the UK, introduced through Hindustan Unilever's pioneering hatchery project in Chennai, India.
- French technology introduced through technical consultancy from France Aquaculture to MPEDA, Government of India, under the OSSPARC project.
- American technology introduced through technical consultancy from Aquatic Farms, Hawaii, to MPEDA, Government of India, under the TASPARC project.
- Availability of trained manpower: By the time *P. vannamei* was introduced in India, skilled personnel were already available to operate hatcheries.
- Infrastructure: Well-designed and well-constructed hatchery facilities were already available for *P. vannamei* operations.
- Market: In the early years of *P. vannamei* introduction, the demand–supply gap favoured hatchery seed producers.

Finally, while quality is the bottom line for sustainable hatchery operations, good systems, practices and biosecurity ensures quality.



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Krill-derived nutrients as a risk management strategy

Under challenging farming conditions, they support hepatopancreatic function and recovery of shrimp growth performance from an EHP infection

By Alberto J .P. Nunes, Daranee Seguin and Kiran Kaur

The hepatopancreas is a central organ in shrimp physiology, integrating digestive, absorptive, metabolic and detoxification functions. Structurally, it is part of the midgut and is ventrally connected to the posterior stomach, where digestive secretions are released and mixed with ingested food.

This organ is composed of numerous blind-ending tubules lined with specialised epithelial cells and containing digestive enzymes and lipid-emulsifying compounds essential for nutrient utilisation. Each tubule comprises four main epithelial cell types with distinct but complementary roles (Figure 1).

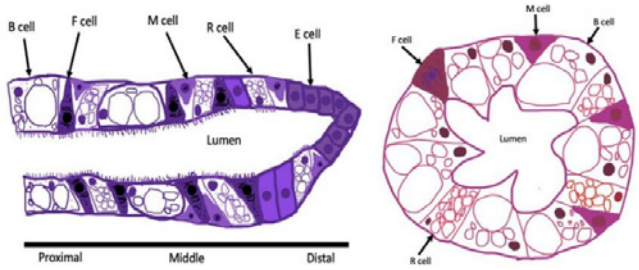


Figure 1. Illustration of hepatopancreatic tubules. Credit: Goh et al., 2023.

- E-cells (embryonic or regenerative cells) are responsible for cell proliferation, renewal and differentiation,
- F-cells (fibrillar cells) synthesise and secrete digestive enzymes, including proteases, lipases and amylases. They directly influence digestive efficiency,
- R-cells (resorptive cells) are primarily involved in nutrient absorption, intracellular digestion, and storage of lipids and glycogen. They play a key role in energy metabolism,
- B-cells are associated with intracellular digestion, waste processing and detoxification through holocrine secretion mechanisms.

The structural and functional integrity of these cells are critical for maintaining optimal growth, feed efficiency and resilience to stress.

Given this central role, hepatopancreatic health is highly sensitive to both nutritional quality and disease challenges. Histopathological assessment of this organ, such as evaluation of R-cell abundance and vacuolisation, B-cell hypertrophy or epithelial degeneration, is widely used in shrimp nutrition and health studies as a functional indicator of how dietary nutrients support hepatopancreatic health, physiological status and performance outcomes.

A primary target under stress and pathogen challenges

Multiple pathogens target shrimp hepatopancreas, directly impairing its function and leading to reduced growth performance. Bacterial infections are particularly detrimental. *Vibrio parahaemolyticus*, the causative agent of acute hepatopancreatic necrosis disease (AHPND), produces toxins that destroy hepatopancreatic cells, leading to severe digestive dysfunction, poor growth and high mortality. Other *Vibrio* species (e.g., *Vibrio harveyi* and *Vibrio alginolyticus*) cause chronic infections that impair organ function and reduce feed intake.

Today, the most economically significant endemic pathogen is the microsporidian *Enterocytozoon hepatopenaei* (EHP) which specifically infects hepatopancreatic cells, significantly reducing digestion and absorption capacity and representing a major cause of slow growth in shrimp farming. Parasitic gregarines (e.g., *Nematopsis* spp., *Cephaloisporidium* spp.) further compromise nutrient absorption by colonising the digestive tract and hepatopancreas.

Together, these pathogens highlight the critical importance of hepatopancreatic health in optimising nutrient absorption, improving disease resistance and supporting overall performance. Targeted nutrition for hepatopancreatic function offers a proactive, farm-level strategy to strengthen shrimp resilience and productivity.

From least-cost to precision nutrition in shrimp feed formulation

Modern shrimp farming operates under continuous stress conditions, including fluctuating water quality, high stocking density and pathogen pressure. Under these scenarios, traditional nutrition approaches based solely on meeting minimal nutrient requirements are insufficient. Instead, precision (or adaptive) nutrition is required, focusing on the strategic inclusion of functional nutrients that actively support metabolic capacity, tissue integrity and resilience.

Shrimp feed formulation has evolved from empirical fishmeal-based recipes through least-cost and digestible-nutrient approaches, towards precision nutrition, where diets are adapted to animal's developmental stage and genetics, production season and pathogen challenges. Within this framework, the hepatopancreas is the primary organ-level target. Nutrients that enhance membrane stability, digestive efficiency, lipid transport and cellular turnover directly determine whether animals can sustain productive function under the stresses that define modern intensive production.

Functional nutrients from krill meal for hepatopancreatic support

Krill-derived ingredients carry a highly integrated package of functional nutrients that directly support hepatopancreatic structure, metabolism and resilience, particularly during nutritional and pathological stress. Unlike conventional ingredients that primarily provide protein and energy, krill meal and krill oil deliver a combination of bioactive compounds, including phospholipids, long-chain n-3 polyunsaturated fatty acids (EPA and DHA), astaxanthin, cholesterol, free amino acids, nucleotides, small peptides and chitin. These act synergistically to enhance digestive efficiency, cellular integrity and metabolic capacity.

Krill lipids have a predominance of phospholipid-bound fatty acids, distinguishing them from fish oil and other marine lipids. In most terrestrial and marine lipid sources, fatty acids are mainly present as triglycerides. This structural feature enhances the bioavailability and incorporation of essential lipids into cell membranes, particularly in hepatopancreatic tissues where lipid transport, storage and metabolism are critical.

Phospholipids play a central role in maintaining membrane fluidity and integrity, facilitating lipid digestion and absorption and supporting hepatopancreatic energy reserves. In addition, they improve the transport and utilisation of cholesterol and triglycerides, thereby contributing to more efficient metabolic regulation and improved resilience under stress conditions.

The lipid fraction of krill is also rich in EPA (20:5n-3) and DHA (22:6n-3), which are essential for maintaining cellular membrane structure and function. These fatty acids modulate membrane fluidity and permeability, directly influencing ion transport processes and reducing the energetic cost of osmoregulation.

This role is particularly relevant for the hepatopancreas, which is highly sensitive to environmental fluctuations such as salinity and temperature. Experimental evidence shows that diets enriched with krill-derived lipids improve growth performance, feed efficiency and stress tolerance, while also enhancing the deposition of EPA and DHA in shrimp tissues.

Cholesterol from krill meal further contributes by supporting membrane stability and serving as a precursor for moulting hormones. Importantly, the association of cholesterol with phospholipids enhances its absorption and transport efficiency, allowing krill meal to partially spare supplemental cholesterol in formulated diets without compromising performance. This is particularly relevant in low fishmeal formulations, where endogenous cholesterol supply may be limiting.

Astaxanthin, a key carotenoid present in krill meal, adds a strong antioxidant and immunomodulatory dimension to its functional profile. Astaxanthin contributes to the stabilisation of cellular membranes and protects hepatopancreatic cells from oxidative damage associated with stress and infection. Its antioxidant activity supports immune competence and reduces the impact of reactive oxygen species generated during environmental or pathological challenges. These combined effects support overall physiological robustness and immune competence during high-risk production periods.

Krill meal contains high levels of natural feeding stimulants, including free amino acids (e.g., arginine, glycine and proline), nucleotides and low-molecular-weight peptides. These compounds are potent chemo-attractants, enhancing feed detection, ingestion and palatability. Nucleotide concentrations in krill meal are particularly high, comprising predominantly monophosphates (e.g., AMP, IMP, GMP), known to stimulate feeding responses in crustaceans. Small peptides, largely below 1kDa, facilitate rapid diffusion in water and enhance sensory detection, contributing to improved feed intake and nutrient utilisation. These effects are especially important under disease or stress conditions, where feed intake is often compromised.

The functional benefits of chitin, present in low levels and finely distributed within krill meal, are related to immune stimulation and gut health. Unlike more recalcitrant chitin sources, krill-derived chitin is more bioavailable and exerts immunomodulatory effects, including the activation of innate immune responses and the enhancement of antimicrobial defenses. It may also contribute to the modulation of gut microbiota, indirectly supporting digestive efficiency and disease resistance.

Collectively, these functional nutrients contribute to maintaining integrity of the hepatopancreas by supporting key processes such as membrane stability, lipid transport, intracellular digestion and cellular turnover. This integrated mode of action is particularly relevant under challenging conditions, where hepatopancreatic dysfunction is often associated with reduced R-cell activity, impaired nutrient absorption and compromised energy metabolism. By enhancing both structural and functional aspects of the hepatopancreas, krill-derived nutrients help sustain metabolic efficiency and support recovery of growth performance even under disease pressure (Figure 2).

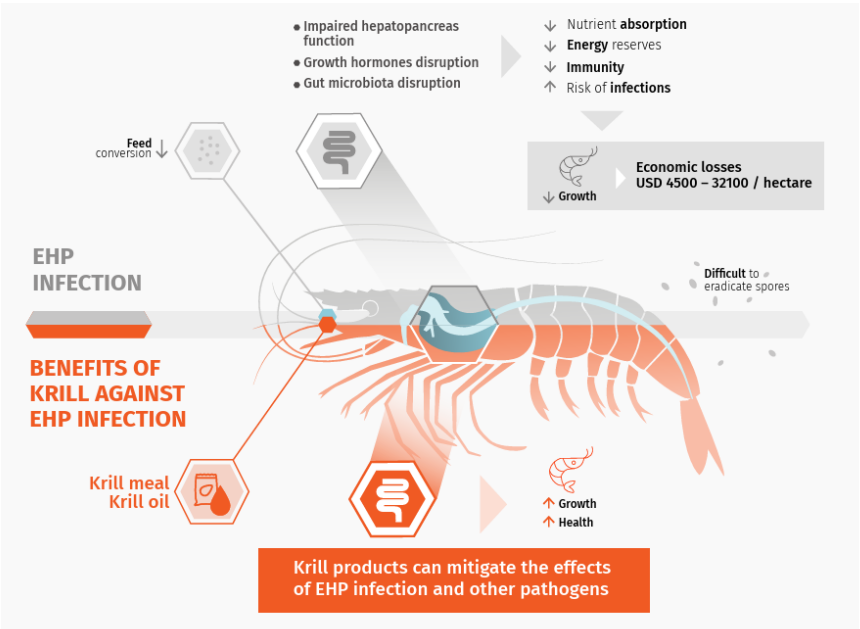
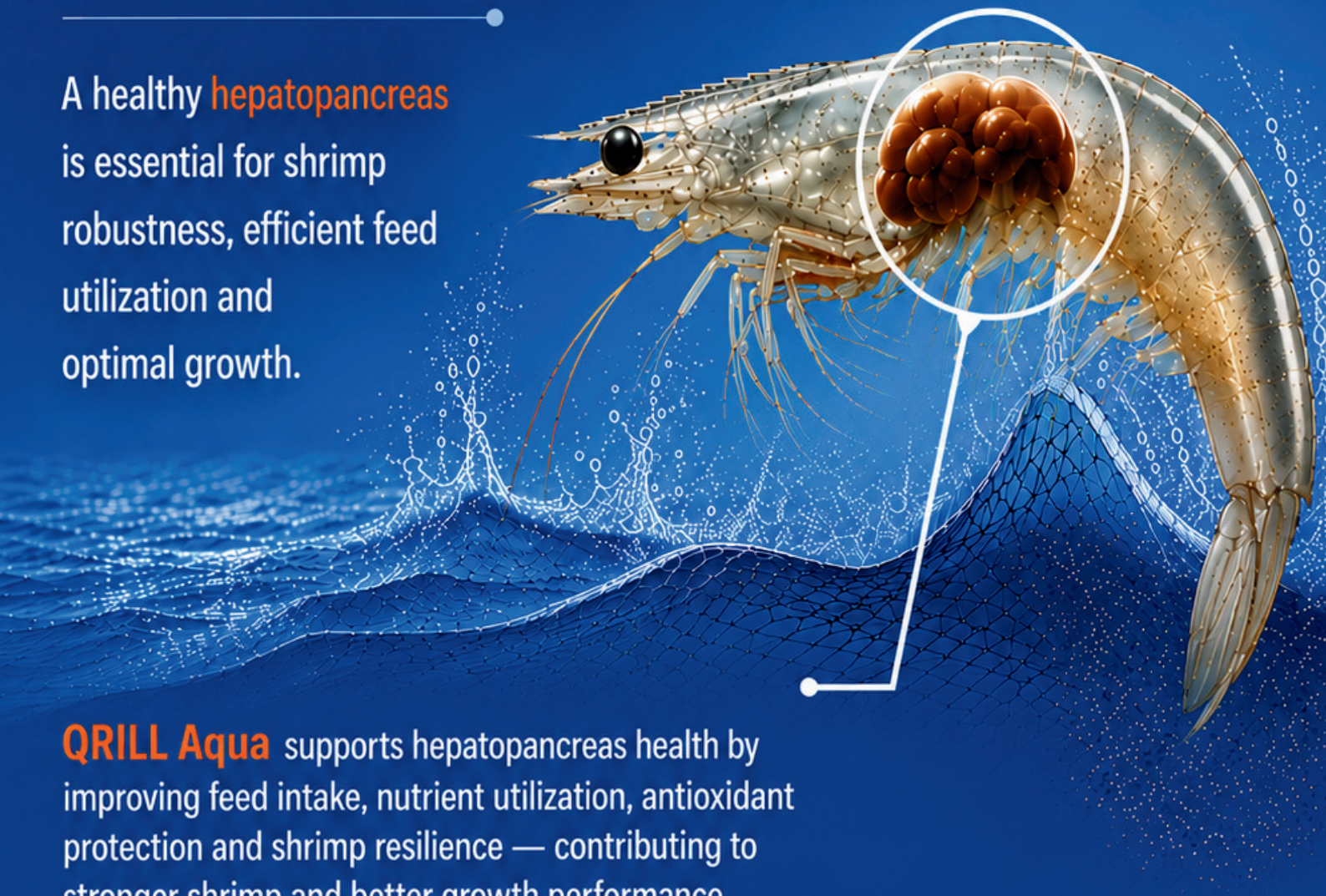


Figure 2. Functional nutrients from krill meal for shrimp hepatopancreatic support.

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A series of recent studies highlights the nutritional and functional benefits of incorporating krill-derived nutrients into shrimp diets to boost hepatopancreatic health under disease challenge.

Supporting hepatopancreatic function when challenged by EHP

Two independent EHP challenge trials provide consistent quantitative evidence. In the first trial conducted at the Aquaculture Pathology Laboratory, University of Arizona, USA, 400 *Penaeus vannamei* were stocked in 20 independent 90L tanks. There were four replicates per treatment. Five diets were tested:

- a non-infected negative control (NEG),
- an infected positive control (POS),
- three treatment diets containing krill-derived ingredients- 3% krill meal (KM3), 10% krill meal (KM10), and 2% krill oil (KO2).

Shrimp were fed their respective diets for 35 days prior to challenge, followed by experimental infection with EHP via a single feeding of infected hepatopancreatic tissue. The trial lasted 73 days, including 38 days post-infection. Growth performance, survival and EHP load (via qPCR) were assessed, while hepatopancreatic health was evaluated through histopathological analysis, focusing on R-cell vacuolisation as an indicator of nutrient absorption and metabolic activity.

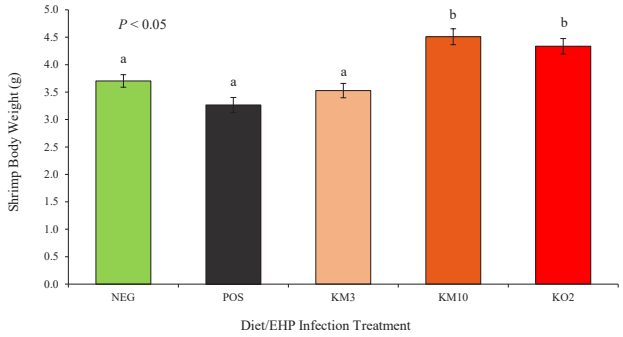


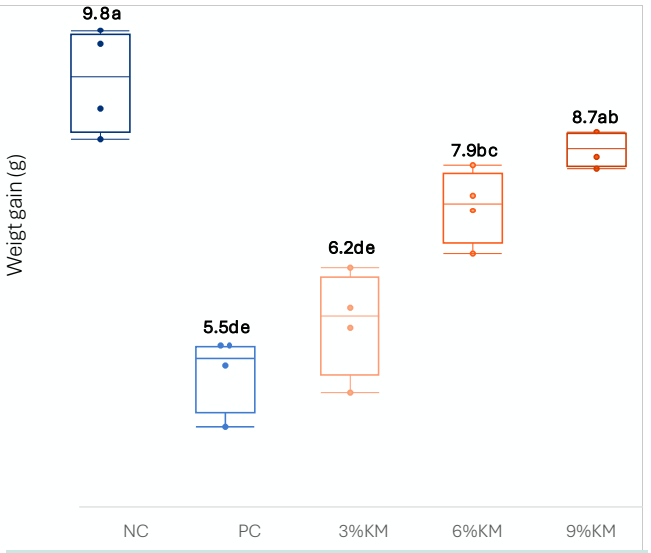
Figure 3. Shrimp mean body weight following EHP challenge (± standard error) at a trial conducted at the Aquaculture Pathology Laboratory, University of Arizona, USA. All shrimp were subjected to EHP challenge, except those in the negative control (NEG-CTL) treatment. Data values with same letters indicate no significant differences among dietary treatments according to Tukey's HSD test at p < 0.05. Burri et al., 2024.

This trial demonstrated that dietary inclusion of krill meal (KM) or krill oil (KO) can partially mitigate the negative effects of EHP infection on shrimp growth performance. Higher inclusion levels, 10% KM (4.6 ± 0.4g) and 2% KO (4.4 ± 0.4g), resulted in significantly greater final body weights compared to the infected control (POS: 3.3 ± 0.3g), and also outperformed the lower inclusion level (KM3: 3.5 ± 0.3g) and the non-infected control (NEG: 3.7 ± 0.2g), indicating a recovery of growth potential under disease pressure (Figure 2).

Histological analysis showed that EHP infection reduced hepatopancreatic R-cell vacuolisation, reflecting impaired nutrient absorption, digestion and energy storage, whereas krill-based diets counteracted this effect, suggesting improved cellular functionality. These findings highlight that krill-derived nutrients help maintain functionality of the hepatopancreas even under adverse conditions, supporting growth performance through improved metabolic efficiency.

Validation under applied conditions

Further validation was obtained under controlled experimental conditions at the Directorate of Incubation and Vocational Training in Aquaculture, Tamil Nadu Dr J. Jayalalithaa Fisheries University (DIVA–TNJFU) in India. Apparently healthy and retarded growth juvenile shrimp (~4 g initial body weight) were obtained from commercial farms and were stocked in a tank system, with four replicates per treatment and 60 shrimp per tank. Four diets with graded krill meal inclusion levels (3%, 6% and 9%) were tested over a 56-day feeding period to assess growth performance, survival, hepatopancreas histology and EHP load. Treatments included a negative control (NC; non-infected shrimp) and a positive control (PC; EHP-infected shrimp fed a control diet without krill meal).



NC: negative control without EHP fed on control diet ;
PC: positive control with EHP fed on control diet;
3%KM: EHP infected shrimp fed with 3% krill meal
6%KM: EHP infected shrimp fed with 6% krill meal
9%KM: EHP infected shrimp fed with 9% krill meal
Source: Uma et al., 2025 in press

Figure 4. Body weight gain of *Penaeus vannamei*, mean± standard error) following EHP challenge at DIVA–TNJFU, India. All treatments, except the NC (negative control), were infected with EHP. Data values with same letters indicate no significant differences among dietary treatments according to Tukey's HSD test at $p < 0.001$ (Burri et al., 2024).

A clear dose-dependent pattern of improvement was observed across weight gain, specific growth rate (SGR) and survival. EHP infection significantly reduced growth and survival in positive control (PC), whereas dietary inclusion of krill meal progressively improved outcomes (Table 1). Survival increased from 62.5% in the PC group to 80.9% in the 9%KM group, comparable to the non-infected control (87.6%). Similarly, body weight gain improved from 5.46 ± 0.28g (PC) to 8.74 ± 0.13g in 9%KM, approaching the performance of non-infected shrimp (9.78 ± 0.39g). Growth metrics followed a similar trend, with specific growth rate (SGR) increasing from 9.75% in PC to 15.61% in 9%KM. Feed efficiency also improved markedly, as reflected by a reduction in FCR from 2.61 (PC) to 1.53 in the highest krill meal inclusion group.

Importantly, these performance improvements were supported by both histopathological evidence of preserved R-cell vacuolisation and EHP count in hepatopancreas. EHP infection resulted in complete

Performance parameters			Treatment diets with krill meal (KM)		
	Negative control (NC)	Positive control (PC)	3% KM	6% KM	9% KM
Survival (%)	87.6 ± 1.5^{a}	62.5 ± 2.5^{c}	67.5 ± 1.1^{bc}	72.5 ± 1.7^{b}	80.9 ± 1.7^{a}
Body weight gain (g/shrimp)	9.78 ± 0.39^{a}	5.46 ± 0.28^{de}	6.20 ± 0.39^{de}	7.90 ± 0.28^{bc}	8.74 ± 0.13^{ab}
Growth (g/day)	0.175 ± 0.007	0.098 ± 0.005	0.111 ± 0.007	0.141 ± 0.005	0.156 ± 0.009
Specific growth rate (%)	17.46 ± 0.70^{a}	9.75 ± 0.51^{de}	11.07 ± 0.70^{de}	14.11 ± 0.49^{bc}	15.61 ± 0.24^{ab}
FCR	1.29	2.61	2.28	1.78	1.53
R cell(count/10Hp cells)	215	0	55	95	139
EHP copies	0	20,011 ± 2,148	16,973 ± 1,725	12,293 ± 1,250	9,743 ± 1,123

Table 1. Growth performance and histopathological evidence of EHP infected shrimp (~4g, initial weight) fed different krill meal levels in diets in comparison to non-infected shrimp over 56 days. There were four replicates for each treatment and 60 shrimp per tank. Values are mean ± standard error (n = 4). Data with different letters is significantly different ($p < 0.001$). Source: Uma et al., 2025 (in press).

loss of hepatopancreatic R-cell vacuolisation in the positive control, indicating severe impairment in nutrient absorption and metabolic activity. In contrast, krill meal inclusion preserved R-cell integrity in a dose-dependent manner, with substantial recovery observed at higher inclusion levels (up to 139 R-cells per 10 HP cells in 9%KM).

Consistent with this observation, EHP load decreased progressively with increasing krill meal inclusion, from 20,011 ± 2,148 copies in the PC group to 9,743 ± 1,123 copies in 9%KM. This reduction suggests improved resilience to infection and/or enhanced capacity to limit pathogen proliferation.

Conclusion

The findings demonstrate that krill-derived nutrients play a functional role beyond basic nutrition by directly supporting hepatopancreas integrity and performance under disease challenge. Across these independent studies, dietary inclusion of krill meal consistently improved growth performance, survival and feed efficiency while preserving hepatopancreatic structure, notably through the maintenance or recovery of R-cell abundance and vacuolisation, which are key indicators of nutrient absorption and metabolic activity.

In parallel, reductions in EHP load suggest that such nutrients may enhance host resilience not only by improving digestion and energy status but also by modulating physiological and possibly immune responses. These effects are likely driven by the unique composition of krill, which is rich in phospholipid-bound omega-3 fatty acids, choline, astaxanthin and other bioactive compounds that support membrane integrity, lipid metabolism and cellular function.

Trials demonstrated that krill-derived functional ingredients serve as a preventive, risk-management tool, with strongest benefits at 6–10% krill meal or 2% krill oil inclusion. These interventions are most valuable during high-risk phases, including EHP-endemic production cycles, periods of environmental instability and diet transitions when hepatopancreatic reserve capacity is under greatest pressure. By supporting hepatopancreatic functions during these critical windows, krill supplementation helps deliver more consistent production, reduced crop variability, improved economic returns and ultimately strengthen adoption confidence across the industry.

At a time when global resources are under strain, the responsibly managed krill fishery provides essential proteins and omega-3s, which are vital nutrients for animal and human health. The krill fishery is regulated by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). It is a fishery with the lowest by-catch. Scientific studies conclude that the by-catch in the Antarctic krill fishery, ranging from 0.1%-2.2%, is significantly lower than other fisheries. The latter has a range of 10% to 55%.

Aker QRILL Company is certified by Marine Stewardship Council (MSC) with 100% sustainable and traceable records. Certified by Friend of the Sea, the fishery as a whole has received an 'A' rating by Sustainable Fisheries Partnership.

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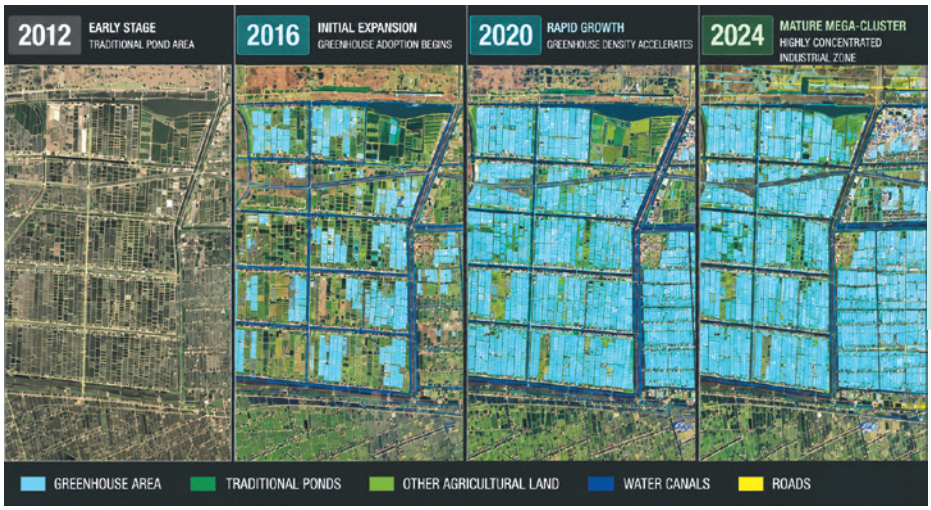
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From rapid expansion to efficiency optimisation: The evolution of China's greenhouse shrimp farming

By Alban Caratis, Jean-Benoît Darodes de Tailly and Li Yi



Greenhouse farms in Fengli, Rudong county (China) between 2012, 2016, 2020 and 2024

Over the last decade, China has developed one of the world's most unique and rapidly evolving shrimp production systems: small-scale greenhouse shrimp farming, commonly referred to as the "Rudong model" . Initially developed in Rudong county, Jiangsu province, this production approach transformed shrimp farming by enabling high-density, multi-cycle production under highly controlled environmental conditions.

More importantly, greenhouse systems allow shrimp farming to expand into regions where seasonal temperature fluctuations previously prevented year-round production. In the provinces of Jiangsu and Shandong, where winter temperatures can remain below freezing for extended periods, greenhouse infrastructure made continuous shrimp production possible.

What initially emerged as a simple climate adaptation strategy progressively evolved into one of the most sophisticated intensive shrimp farming systems in the world. Its rapid expansion also coincided with a major transformation of China's shrimp market.

Between 2015 and 2020, as China became one of the world's largest shrimp importers, the need for stable domestic production increased considerably. During this period, China's shrimp trade balance shifted from a surplus to a deficit exceeding 400,000 tonnes (Figure 1).

Consequently, the Rudong model emerged as an attractive solution capable of supplying fresh shrimp year-round to major urban markets while reducing dependence on imports and seasonal production. In the small town of Fengli alone, one of China's largest greenhouse hubs, the number of greenhouses increased from fewer than 100 in 2012, to more than 20,000 in 2024.

Today, greenhouse shrimp farming systems are widely distributed across Jiangsu, Shandong, Hebei, Fujian, Guangdong and even inland provinces. Industry experts estimate that more than 200,000 greenhouses are now operating across China, representing nearly one-third of national shrimp production.

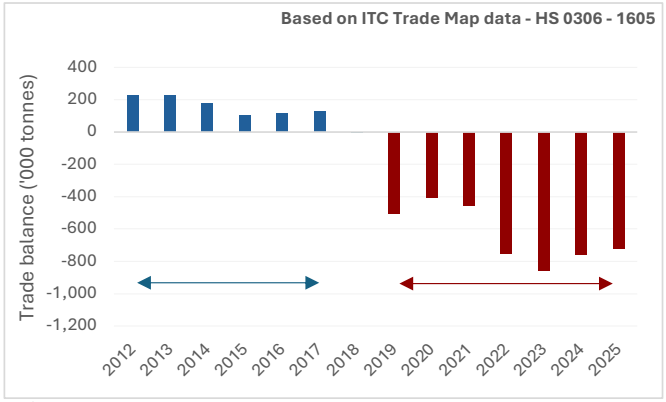


Figure 1. China's shrimp trade balance reversal (2012 - 2025).

The new challenges of intensive greenhouse farming

While the Rudong model successfully transformed the economics of shrimp production in China, the sector is now entering a more demanding phase of development.

During the early years of expansion, the success of this farming model was largely driven by strong domestic demand for shrimp and the ability to produce fresh shrimp close to major urban markets such as Shanghai and Beijing. As a result, profitability was linked to production intensity and favourable market prices. Under these conditions, producers could tolerate relatively high biological variability as long as harvest volumes remain attractive.

However, after years of rapid growth, producers now face a far more competitive environment. Increasing shrimp imports, particularly from Ecuador, have progressively pressured domestic prices. At the same time, the rapid expansion of greenhouse farming itself substantially increased domestic production volumes, contributing to market saturation in several regions.



Figure 2. Left, the latest greenhouse generation with integrated auto feeding, LED lighting, centralised biomass heating, smart monitoring sensors and right, photovoltaic integration.

Production costs have also continued to rise. Feed remains the largest operational expense, while infrastructure costs have increased as greenhouse systems become more technologically advanced. Modern farms now integrate centralised aeration systems, automated feeding, biomass heating, environmental sensors, photovoltaic integration and standardised production protocols (Figure 2). In some regions, greenhouse production has evolved into industrial aquaculture parks operating under centralised technical management.

Performance and economics of modern greenhouse farming systems

Most greenhouse ponds are now standardised 400m² units, stocking shrimp post larvae (PL) at densities approaching 175PL/m². Field observations by Phileo teams, conducted across commercial farms in Rudong, reported that optimised systems showed:

- Survival rates between 70 and 80%,
- Harvest weights between 20 and 30g,
- Feed conversion ratios (FCRs) ranging from 1.1 to 1.3,
- Harvest biomass between 3 and 4kg/m²/cycle.

However, under favourable conditions, annual productivity may therefore reach 7 to 8kg/m² over two production cycles per year.

Lower profit margins

Despite these impressive productivity levels, greenhouse farm economics have become increasingly dependent on biological performance and operational efficiency. Rising feed costs, higher infrastructure investments and lower shrimp prices have significantly narrowed profit margins.

While greenhouse systems generally provide more stable survival rates than traditional pond farming, FCRs have emerged as one of the most critical drivers of profitability. Under current market conditions, even relatively small improvements in feed efficiency can generate substantial economic gains.

Economic simulations based on contemporary Chinese greenhouse farming conditions illustrate how moderate improvements in FCR, survival and harvest weight can dramatically transform farm profitability (Table 1).

Parameter/cost item	Scenario 1 (Low)	Scenario 2 (Intermediate)	Scenario 3 (High)
FCR	1.4	1.3	1.2
Survival	75%	75%	75%
Harvest weight	22.50g	25.00g	27.50g
Greenhouse size	400m²	400m²	400m²
Stocking density	175 PL/m²	175 PL/m²	175 PL/m²
Stocked post larvae (nos)	70,000	70,000	70,000
Harvested shrimp (nos)	52,500	52,500	52,500
Biomass/cycle	1180kg	1,313kg	1,444kg
Selling price (USD)	5.30/kg	5.56/kg	5.80/kg
Revenue/cycle (USD)	6,259	7,301	8,374
Feed used (kg)	1,654	1,706	1,733
Feed cost USD1.39 /kg)	2,299.06	2,371.34	2,408.87
Energy cost (USD)	1,250	1,250	1,250
Post-larvae cost (USD)	347	347	347
Labour cost (USD)	486	486	486
Costs for water management & probiotics (USD)	347	347	347
Miscellaneous costs (USD)	417	417	417
Infrastructure depreciation (USD)	1,806	1,806	1,806
Total cost/cycle (USD)	6,952	7,024	7,062
Gross profit/cycle (USD)	-693	277	1,312
Annual profit in USD (2 cycles/year)	-1,386	554	2,624

Table 1. Impact of biological performance on greenhouse shrimp farm economics.

Yeast probiotic for digestive health: Microscopic organism, major economic impact

The gut plays a central role in shrimp performance, acting as the main site for digestion, nutrient absorption and immune defense. Maintaining digestive integrity is therefore critical in intensive greenhouse systems, where shrimp are exposed to high stocking densities, elevated microbial pressure and environmental fluctuations associated with biomass accumulation. In regions such as Rudong, intensive greenhouse systems are frequently associated with digestive disorders and opportunistic pathogens such as *Enterocytozoon hepatopenaei* (EHP), which have become major production challenges for farmers.

In this context, a large-scale commercial field project was conducted by Phileo and several greenhouse farms in Rudong County to evaluate the impact of Actisaf® Sc 47 supplementation on digestive performance and farming efficiency under intensive greenhouse conditions. This is a yeast probiotic of a selected and proprietary *Saccharomyces cerevisiae* strain (CNCM I-4407), selected for its biological activity within animal digestive systems, and is a primary fermentation product processed in a micro-spherule form delivering long stability. Previous studies in fish and shrimp have demonstrated its potential to support beneficial

microbiota, improve digestive balance and help modulate inflammatory responses associated with stress and pathogenic challenges.

The project evaluated 38 commercial greenhouse units and compared Actisaf Sc 47 supplemented ponds against non-supplemented control units managed under similar commercial practices. The yeast probiotic was applied daily through feed top coating throughout the production cycle.

Under commercial conditions, supplementation consistently improved both technical and economic performance. The most significant effect was observed on feed efficiency. Supplemented units achieved an average FCR of 1.08 compared to 1.19 in control ponds (Figure 3). Average harvested biomass increased from 788 to 861kg per greenhouse, corresponding to an improvement of approximately 9.2% (Figure 4). Importantly, this improvement was achieved while simultaneously producing larger shrimp and higher total biomass. Average weight of harvest increased from 14.4 to 15.2g, while survival improved from 86.2% to 88.2%.

These biological improvements translated directly into better production economics. Despite the additional supplementation cost, average production cost decreased from USD4.31/kg in control units to USD4.10/kg in supplemented ponds (excluding depreciation), illustrating the strong economic leverage associated with feed efficiency improvements under intensive production conditions. Concomitantly, average net profit increased from approximately USD0.81/kg in control units to USD1.10/kg in supplemented units, corresponding to an increase of 36%.

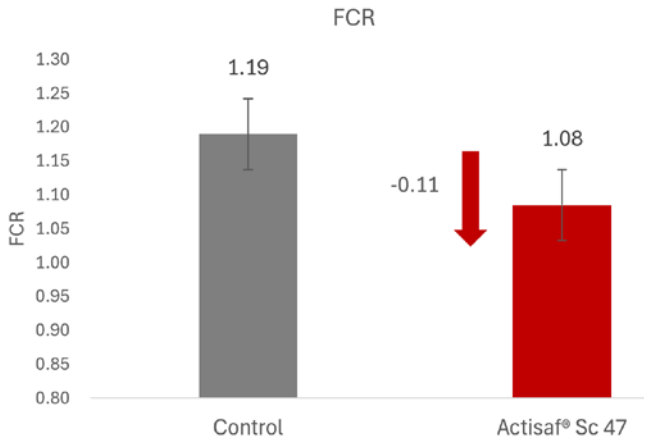


Figure 3. Improvement in feed conversion ratio (FCR) with the supplementation of Actisaf® Sc 47.

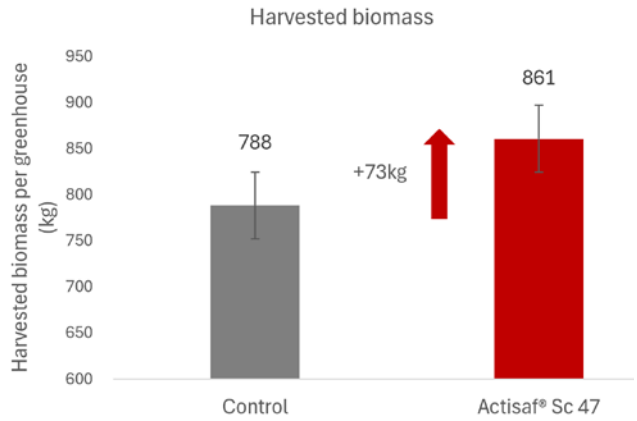


Figure 4. Increase in average harvested biomass per greenhouse with the supplementation of Actisaf® Sc 47, corresponding to an improvement of approximately 9.2%.

To better understand the biological mechanisms behind these results, regular Digescan™ evaluations were conducted throughout the production cycle to monitor gut and hepatopancreas condition. Both groups maintained good digestive health throughout the trial, although a numerical improvement of gut health scores was observed with the supplementation of Actisaf Sc 47.

"..validated microbial strains can deliver measurable biological and economic benefits when integrated into a nutritional strategy."

At the same time, higher productivity was achieved without compromising water quality stability. Despite producing significantly more biomass, supplemented units were able to maintain water quality parameters comparable to control ponds throughout the cycle. This stability may partly be explained by the improved feed efficiency observed in supplemented shrimp. Thanks to the lower FCR, more shrimp biomass was produced per kilogram of feed distributed, potentially limiting excess nutrient release and organic waste accumulation within the system.

Microbial management as the next performance frontier

Taken together, these results highlight the growing importance of digestive efficiency as a key driver of technical and economic performance in modern shrimp farming systems. Importantly, the study also demonstrates that the strategic inclusion of beneficial microorganisms can significantly improve feed efficiency and overall production outcomes.

While probiotics are often applied directly by farmers at pond level, this approach can result in variable product quality and inconsistent field performance. In contrast, the results obtained with Actisaf SC 47 illustrate how carefully selected and scientifically validated microbial strains can deliver measurable biological and economic benefits when integrated into a nutritional strategy.

These findings reinforce the opportunity for feed manufacturers to incorporate proven microbial solutions directly into feed formulations. Beyond improving consistency and quality assurance, such an approach may help producers unlock significant performance gains in an increasingly competitive production environment.



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Enhancing feed digestibility and profitability with exogenous fermentation extracts: Part 1 - Finfish

By Hervé Lucien-Brun

Feed accounts for 50 to 70% of total operational costs in fish and shrimp farming. Asia-Pacific dominates the sector, producing roughly 70% of the world's farmed aquatic animals and around 26% of global aquafeed output. Yet aquaculture nutrition in the region, as in the rest of the world, still lags behind terrestrial livestock production in feed efficiency. Two factors explain this gap: the science of species-specific nutritional requirements is still young, and the sector is under growing pressure to replace marine-derived proteins with plant-based alternatives, for both economic and environmental reasons.

Fishmeal and fish oil prices have averaged USD1,496 and USD2,348 per tonne respectively in recent years, spiking even higher after the cancellation of the 2023 Peruvian anchovy season — making soy, wheat, rapeseed and other plant proteins an economic and environmental necessity, despite their imbalanced amino acid profiles, anti-nutritional factors (ANFs) and poor digestibility. Continued reliance on wild-caught fish for fishmeal and fish oil also undermines the ecological credentials of farmed seafood and conflicts with the sustainability commitments now expected by export markets, retailers and certification bodies.

Closing this gap is the central objective of precision nutrition in aquaculture: formulating feeds that match, as closely as possible, the real digestive and metabolic capacities of each species, so that plant-based ingredients can be used at higher inclusion rates without sacrificing growth performance. The practical payoffs are a reduction in nutrient waste and feed cost, and less pressure on wild fish stocks and aquatic ecosystems. Reaching this level of precision requires two prerequisites that remain underdeveloped in aquaculture compared with terrestrial livestock: robust ingredient-level digestibility data and exogenous enzymes capable of working reliably across the wide temperature range and alkaline pH typical of aquatic environments.

Terrestrial monogastric nutrition — poultry and swine — offers a useful point of comparison. Decades of research have produced standardised digestible amino acid values and ideal-protein models for these species, and exogenous enzymes such as phytases and proteases have been routine formulation tools since the 1990s, allowing higher plant-ingredient inclusion at lower crude protein levels. Aquafeed formulation is only now approaching that level of precision and does so under constraints that terrestrial nutrition does not encounter hundreds of farmed species with very different digestive anatomies, far less complete digestibility databases, and an enzymatic activity that depends directly on water temperature and pH, since fish and shrimp — unlike homeothermic livestock — cannot regulate their internal digestive environment. Closing this gap means adapting, rather than simply transposing a precision-nutrition toolkit already proven for livestock production.

Enzymatic gap of fish and shrimp

However, farmed aquatic organisms — whether finfish or shrimp — have evolved a digestive system optimised for marine and aquatic food sources, not for the plant-based ingredients that now increasingly dominate commercial aquafeed formulations. This fundamental mismatch between the enzymatic capacity of these animals and the biochemical composition of terrestrial plant ingredients remains a critical bottleneck for feed efficiency across the region. Key cultured species such as *Litopenaeus vannamei*. whose feed segment is projected to grow at 6% compound annual growth rate (CAGR) through 2029, and pangasius. which dominates the Asia-Pacific aquafeed market with approximately 43% market share, are particularly affected by this challenge.

Exogenous enzymes

The use of exogenous enzymes offers a practical and cost-effective solution to bridge this gap. By breaking down molecules that aquatic organisms cannot efficiently digest on their own, these feed additives have the potential to significantly improve nutrient utilisation and unlock

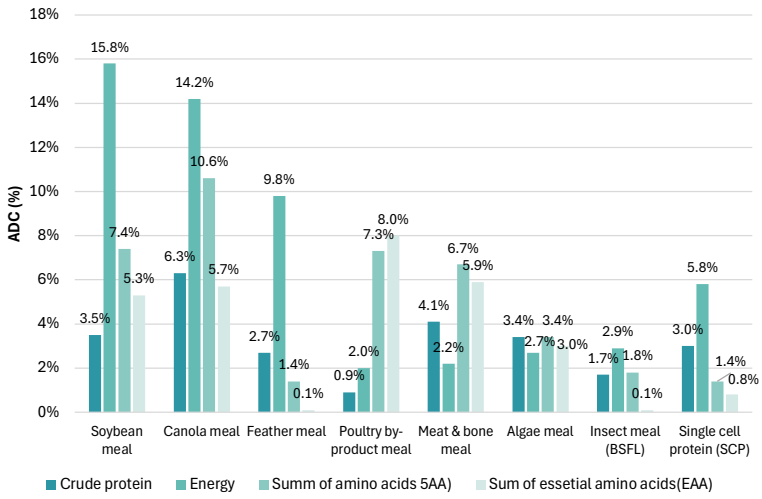


Figure 1. Improvement of nutrient apparent digestibility coefficient from several ingredients on rainbow trout feed when diets were supplemented with Jefo Pro Solution (JPS).

the full nutritional value of plant-based aquafeeds — a critical lever for competitiveness in a region where feed ingredient prices surged by 20 to 30% in 2022, directly squeezing farm profitability. These enzymes also show an effect to limit the impact of ANFs.

Plant-based proteins are long-chain and poorly digested by aquatic organisms. Multi-component fermentation extracts are enzymes that break them down into absorbable peptides and/or free amino acids, but they require specific pH and temperature conditions to work. The addition of exogenous proteases, through their action, also helps modify and optimise the amino acid profile of these plant proteins.

Since aquatic organisms are cold-blooded and live in generally alkaline environments, exogenous multi-component fermentation extracts used in aquafeed must be able to work across a wide temperature range and at alkaline pH.

This study investigates the augmentation of aquafeed digestibility with inclusion of a commercial multi-component fermentation extract, Jefo Pro Solution (JPS, JEFO Nutrition, Canada). which exhibits a high multi-component fermentation extract activity under broad thermal and alkaline pH conditions.

Evidence from *in vivo* apparent digestibility trials

Raising ADC of nutrient and energy digestibility with trout

A study conducted by Lee et al. (2020) evaluated the efficacy of an exogenous multi-component fermentation extract (JPS), in enhancing nutrient digestibility of feed ingredients in rainbow trout (*Oncorhynchus mykiss*) diets. It included *in vivo* measurements of nutrient digestibility of 17 ingredients (plant and animal origin) with or without the supplementation of JPS in the diets of rainbow trout.

The experimental diets were formulated by blending 70% of a reference diet - based on fishmeal, sardine and yttrium oxide as an inert tracer - with 30% of each selected test ingredient. A total of eight alternative protein sources were screened under both supplemented and unsupplemented conditions. Fish were housed in duplicate tank units throughout the trial.

Faecal collection was carried out on day 5 following light anaesthesia, yielding approximately 70g of wet faeces per tank. The pooled samples were subjected to a comprehensive analysis covering proximate composition, energy content, amino acid profiles and mineral concentrations. Nutrient digestibility was subsequently determined by comparing test and reference diet compositions using established calculation methods (Bureau et al., 1999).

The findings underline the versatility of JPS in significantly boosting the apparent digestibility coefficients (ADC) of plant- and animal-based ingredients intended as fishmeal alternatives in commercial aquafeed.

The results (Figure 1) demonstrated that exogenous protease activity supplementation is an effective tool to improve the nutritional value of common aquafeed ingredients, particularly plant-based ones, in rainbow trout diets. This supported its potential use

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Nutrient	Soybean meal	Soybean meal +JPS	P value	Canola meal	Canola meal + JPS	P value
Dry matter	54.5 ± 0.5	63.9 ± 2.8	0.082	42.0 ± 4.3	51.9 ± 3.5	0.216
Crude protein	83.8 ± 1.7	86.7 ± 3.7	0.558	76.8 ± 1.0	81.6 ± 2.5	0.210
Energy	63.2 ± 0.3	73.2 ± 3.5	0.103	54.8 ± 2.6	62.6 ± 1.9	0.136
Essential and semi-essential amino acids						
Arginine	92.2 ± 0.3	93.9 ± 0.7	0.151	92.5 ± 1.8	94.9 ± 1.3	0.386
Cysteine	61.5 ± 2.0	72.0 ± 1.2	0.046	72.4 ± 5.1	77.2 ± 2.4	0.483
Histidine	84.6 ± 0.5	89.0 ± 0.8	0.044	86.2 ± 3.1	88.7 ± 0.8	0.529
Isoleucine	80.7 ± 0.0	85.8 ± 0.7	0.020	75.5 ± 3.6	82.3 ± 2.2	0.248
Leucine	78.3 ± 0.3	83.9 ± 1.9	0.102	79.0 ± 4.0	85.2 ± 1.8	0.293
Lysine	88.1 ± 0.1	92.2 ± 0.5	0.016	86.6 ± 2.2	90.4 ± 0.4	0.239
Methionine	82.0 ± 0.9	89.5 ± 2.2	0.086	87.5 ± 2.0	90.6 ± 0.6	0.274
Phenylalanine	84.3 ± 0.2	87.9 ± 1.0	0.076	81.9 ± 2.9	85.8 ± 0.2	0.319
Threonine	74.0 ± 0.4	80.5 ± 0.7	0.015	71.1 ± 4.6	78.2 ± 3.5	0.340
Tryptophan	88.4 ± 1.1	85.7 ± 1.2	0.245	87.8 ± 3.8	87.4 ± 3.8	0.946
Tyrosine	87.7 ± 0.6	89.4 ± 1.0	0.285	85.8 ± 3.7	87.4 ± 0.8	0.722
Valine	78.1 ± 0.0	84.7 ± 1.3	0.034	72.8 ± 3.9	79.8 ± 2.1	0.253
Sum AA	80.7 ± 0.2	86.7 ± 1.1	0.035	78.9 ± 3.9	84.3 ± 2.0	0.334
Sum EAA & semi-EAA	82.9 ± 0.2	87.3 ± 1.0	0.048	81.2 ± 3.3	85.8 ± 1.6	0.339

[1]Negative values were rounded up to zero and values above 100 were rounded down to zero. Many factors can influence the apparent digestibility coefficients for a nutrient and could lead to negative ADC values or values greater than 100. Nutrients that are very low in an ingredient or have a true digestibility near to either threshold can yield in values less than 0 and greater than 100.

Table 1. Apparent digestibility coefficients (ADC) of dry matter, crude protein, energy and amino acids for different ingredients in rainbow trout feed (Mean ±SEM, n = 2 tanks per ingredient) .

in commercial aquaculture feed formulations. The most frequent improvements were seen in individual amino acid digestibility values. Of 18 ingredients tested, 12 showed improved digestibility of at least one amino acid with JPS supplementation.

The greatest improvements were observed when the protease complex was added to soybean meal, in apparent digestibility of dry matter and that of 13 amino acids, including key limiting amino acids such as methionine, lysine and threonine (Table 1). This is particularly relevant for trout diets, since these amino acids are often deficient and require synthetic supplementation. These improvements are likely due both to direct proteolytic activity on soy proteins and the degradation of ANFs such as trypsin inhibitors, which can otherwise hinder protein utilisation.

Digestibility of aquafeed for striped catfish

This study conducted at Can Tho University (2023) investigated how supplementing diets with a multi-component fermentation extract JPS, affected the digestibility of nutrients in striped catfish *Pangasianodon hypophthalmus*, using five dietary treatments varying in crude protein level (28% or 26%) and whether canola meal partially replaced soybean meal (Table 2).

Ingredients	28%CP-Soy	28%CP-Soy +JPS	26%CP-Soy +JPS	26%CP-Canola +JPS	28%CP-Canola +JPS
Fish meal	3.5	3.5	3.5	3.5	3.5
Soybean meal	49.4	49.4	43.2	39.4	45.6
Canola meal	0.0	0.0	0.0	5.0	5.0
Rice bran	28.2	28.2	34.3	33.1	27.0
Cassava meal	16.0	16.0	16.0	16.0	16.0
$CaCO_3$	1.2	1.2	1.3	1.2	1.2
MCP	0.5	0.4	0.4	0.4	0.4
NaCl	0.7	0.7	0.7	0.7	0.7
JPS	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
PREMIX DSM CA	0.56	0.56	0.64	0.63	0.56
Cost (VNĐ)	12,080	12,137	11,740	11,610	12,007
Proximate (in feed miller- wet basis)					
Crude Protein	28.10	28.10	26.10	26.10	28.10
Lipid	3.73	3.73	4.40	4.37	3.70
Fiber	4.22	4.22	4.28	4.67	4.62
Chemical analysis (in dry basis)					
Crude Protein	31.22	31.5	30.59	29.55	31.39
Hydrolysed fat	5.61	5.96	6.99	6.73	5.62
Crude fat	1.87	2.03	2.49	2.17	2.21
Ash	12.19	12.3	11.57	11.85	11.04
Crude fibre	4.53	4.75	4.53	5.34	4.97
Gross energy (KJ/g)	16.94	16.93	17.15	16.82	17.15

Table 2. The experimental feed formulation (%. wet basis) and dietary chemical compositions digestibility of nutrients in striped catfish *Pangasianodon hypophthalmus*. Using five dietary treatments varying in crude protein level (28% or 26%) and with the partial replacement of soybean meal with canola meal.

Fish of around 50g were reared over 8 weeks in a recirculating aquaculture system with six replicate tanks per treatment. A digestibility trial was then conducted using chromic oxide (Cr_2O_3) as an inert marker, with faeces collected and analysed for ADCs of protein, fat, energy and amino acids.

The results (Table 3) showed that supplementing JPS enzyme consistently improved protein digestibility across treatments. However, total free amino acid of diet adding JPS was higher than the control diet (Table 4).

The 28%CP diet with soybean meal and JPS achieved the highest protein digestibility; the equivalent diet using canola meal performed similarly, suggesting that canola meal can partially substitute soybean meal without significantly reducing digestibility when the enzyme is present (Figure 2). Notably, JPS supplementation also allowed a 2% reduction in dietary protein while maintaining comparable digestibility levels, pointing to a potential cost and efficiency benefit.

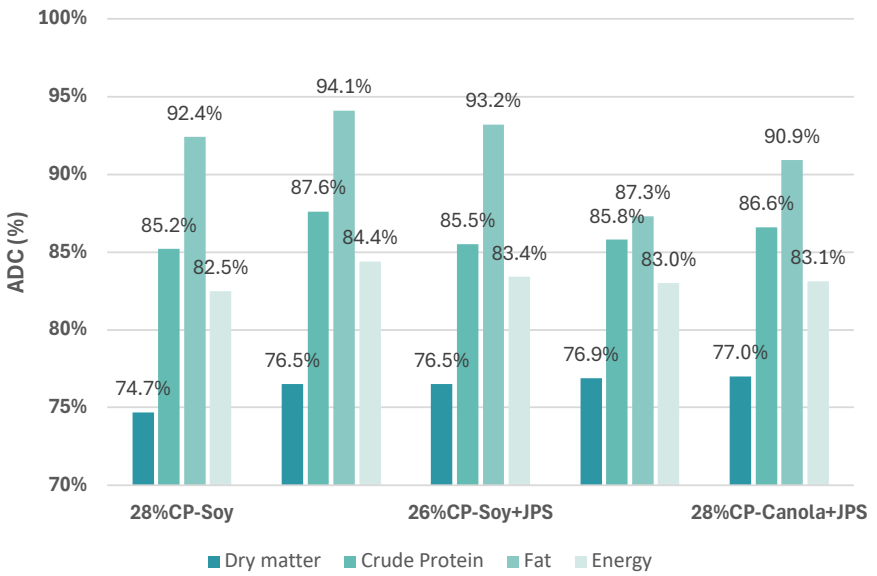
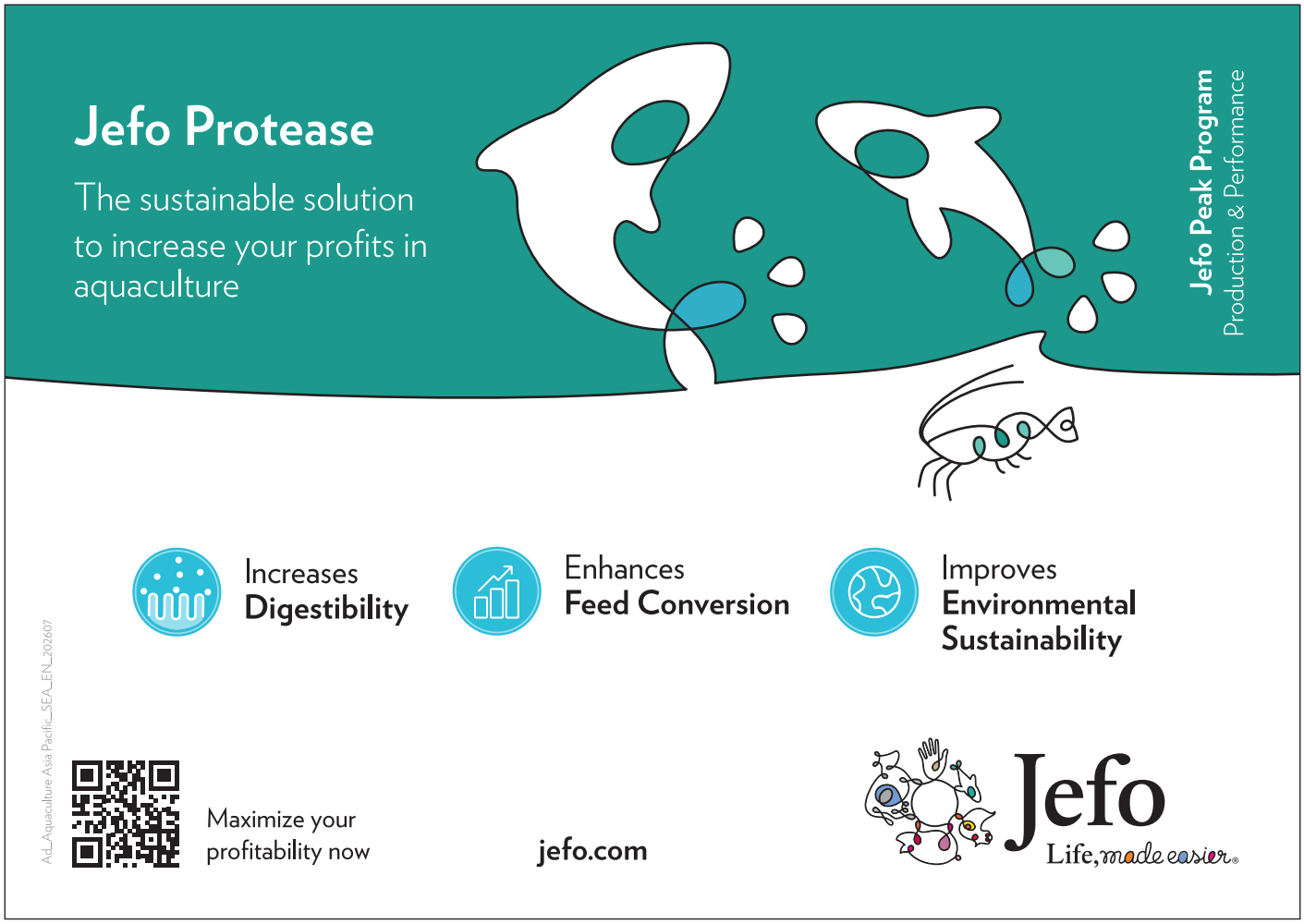


Figure 2. Improvement of nutrient apparent digestibility coefficient (ADC) of feeds for striped catfish *Pangasianodon hypophthalmus* supplemented with Jefo Pro Solution (JPS).



Treatment	28%CP-Soy	28%CP-Soy +JPS	26%CP-Soy +JPS	26%CP-Canola+JPS	28%CP-Canola+JPS	*P value*
Dry matter	74.7 ± 1.12	76.5 ± 1.22	76.5 ± 0.93	76.9 ± 0.29	77.0 ± 1.04	0.5
Crude Protein	85.2 ± 0.87^{b}	87.6 ± 0.28^{a}	85.5 ± 0.38^{b}	85.8 ± 0.40^{b}	86.6 ± 0.31^{ab}	0
Fat	92..4 ± 1.36^{a}	94.1 ± 0.44^{a}	93.2 ± 0.82^{a}	87.3 ± 1.74^{b}	90.9 ± 1.06^{a}	0
Energy	82.5 ± 0.78	84.4 ± 0.38	83.4 ± 0.66	83.0 ± 0.45	83.1 ± 0.70	0.3

Table 3. Apparent digestibility coefficient (ADC%) of experimental feed with striped catfish *Pangasianodon hypophthalmus* supplemented with Jefo Pro Solution (JPS).

Free AA	28%CP-Soy	28%CP-Soy +JPS	26%CP-Soy +JPS	26%CP-Canola +JPS	28%CP-Canola +JPS
Total Free AA	0.75	0.81	0.82	0.83	0.81
Free Aspartic acid	0.04	0.04	0.04	0.04	0.04
Free Threonine	**0.01**	**0.01**	**0.01**	**0**	**0**
Free Serine	0.02	0.02	0.02	0.02	0.02
Free Glutamic acid	0.07	0.06	0.07	0.07	0.07
Free Glycine	0.01	0.01	0.01	0.01	0.01
Free Alanine	0.03	0.03	0.03	0.03	0.03
Free Cystine/ Cysteine	0.19	0.18	0.18	0.18	0.18
Free Valine	0.01	0.01	0.01	0.01	0.01
Free Methionine	**0.24**	**0.3**	**0.29**	**0.31**	**0.31**
Free Isoleucine	0.01	0	0	0	0
Free Leucine	0.01	0.01	0.01	0.01	0.01
Free Tyrosine	0.01	0.01	0.01	0.01	0.01
Free Phenylalanine	0.01	0.01	0.01	0.01	0.01
Free Histidine	0.01	0.01	0.01	0.01	0.01
Free Lysine	**0.01**	**0.01**	**0.05**	**0.05**	**0.02**
Free Arginine	0.07	0.06	0.07	0.05	0.07
Free Proline	0	0	0	0	0

Table 4. Dietary free amino acids in experimental feed (dry matter basis (g/100g)

Regarding fat digestibility, most treatments performed similarly, except for the 26%CP canola + JPS diet, which stood out. The authors noted that canola inclusion was partly intended to challenge digestibility, and the reduced protein level was designed to test performance under less optimal dietary conditions. Overall, the findings confirm that JPS multi-component fermentation extract supplementation improved both protein and fat digestibility in striped catfish diets. This supports the feasibility of using canola meal as a partial soybean meal replacement when the enzyme is included.

Conclusion

Across two species — rainbow trout and striped catfish, supplementation with the multi-component fermentation extract JPS consistently improved apparent digestibility of protein, energy, and key amino acids in plant-based aquafeed formulations. These results demonstrated that exogenous supplementation with high enzymatic activity is an effective and practical strategy to bridge the digestive gap between aquatic species and plant-based ingredients, through targeted enzymatic activity on proteins and anti-nutritional factors.

From an economic standpoint, the implications are significant. With feed representing a large part of total operational costs in aquaculture, and plant-based ingredient prices having surged by 20 to 30% in recent years, improving nutrient utilisation directly translates into better feed conversion ratios and lower production costs. JPS supplementation also demonstrated the potential to reduce dietary protein levels while maintaining comparable digestibility, and to support the partial replacement of pricier soybean meal with more affordable alternatives such as canola meal — both of which represent meaningful cost-saving opportunities for feed formulators and farmers alike.

Taken together, these findings position JPS as a valuable tool not only for enhancing feed efficiency and supporting more sustainable aquaculture practices, but also as a lever for improving farm profitability in a sector under sustained economic pressure.

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A premium protein source for fishmeal replacement in shrimp feed

Trials in Vietnam and Indonesia demonstrated how a corn protein complex replaced fishmeal in shrimp feeds

By Nguyen Duy Hoa



Shrimp do not follow growth patterns/models of advanced animals; instead, they exhibit stepwise growth after each moult. That is also the reason why fishmeal is one of the essential protein sources in shrimp feed. Not only is fishmeal highly digestible and balanced in essential amino acids, but it is also rich in polyunsaturated fatty acids and bioactive peptides. Fishmeal contains almost no carbohydrates or anti-nutrients and is especially high in cholesterol—a vital precursor for synthesising moulting steroid hormones.

However, the pressure of increasing demand for fishmeal from aquafeeds and piglet feeds, while supply is stagnant, is pushing fishmeal prices higher. There is also growing pressure from buyers and certification organisations to reduce the use of fishmeal in shrimp feed to meet sustainability standards. However, fishmeal replacements must provide premium, digestible protein with a balanced amino acid profile and functional nutrients, especially peptides and cholesterol to maintain nutrient balance and reduce formulation costs.

This article evaluates the challenges and trends in replacing fishmeal with alternatives and introduces a corn protein complex (69% crude protein) that provides an excellent solution for replacing fishmeal in shrimp feed.

Challenges with fishmeal alternatives

Shrimp and carnivorous fish (e.g., marine fish, trout, salmon, eel, etc.) are the primary consumers of fishmeal (Figure 1).

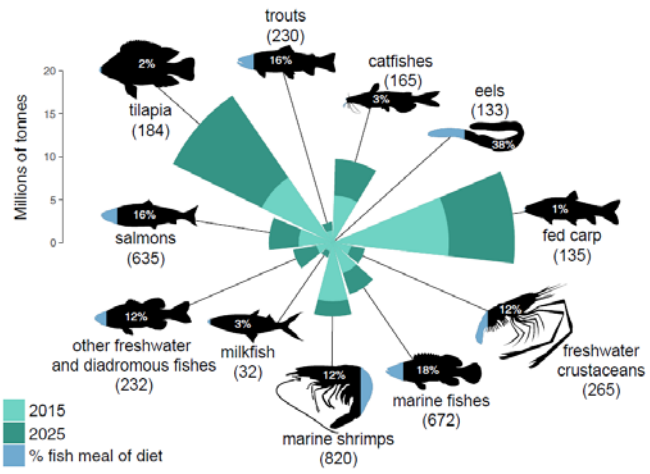


Figure 1. Fishmeal usage in different aqua species (Hua et al., 2019).

Fishmeal is a premium protein with excellent attractability and palatability. Therefore, it addresses the nutritional requirements of carnivorous fish species and shrimp. However, plant-based proteins have their disadvantages as fishmeal alternatives, particularly in essential amino acids. For instance, methionine is limited in soybean meal and lysine is limited in corn gluten meal. Both lysine and arginine are limited in wheat gluten meal.

The high carbohydrate content in plant-based proteins (23-24% in soy proteins and 26.5-27% in corn gluten meal) is another limitation for carnivorous species. In addition, low attractability and high content of anti-nutrients together with the absence of cholesterol are all major barriers for soy proteins to replace fishmeal at inclusions higher than 5%.

Hydrolysed poultry by-product meals and hydrolysed feather meals are also viable alternatives to fishmeal. However, their inclusion rates are limited by their high ash content and low cholesterol level. The optimal inclusion should not be higher than 5%.

Single-cell proteins and insect meals are promising fishmeal alternatives. However, inconsistent product quality, limited production capacity and high prices remain major barriers to their widespread commercial adoption to replace fishmeal.

Excellent ingredient for fishmeal replacement

MOTIV™ (Cargill, USA) is a promising fishmeal alternative. It is a technical product that uses pure protein separation and specialised fermentation processes to create organic acids and bioactive peptides while increasing lysine content and other essential nutrients. It addresses many of the limitations found in other fishmeal alternative protein sources mentioned above.

This corn protein complex has a balanced amino acid (69% protein, high methionine and good lysine content), and is low in carbohydrates (1.7%) and in fibre (< 1%). It does not contain any anti-nutrients.

Motiv is rich in nutrients, including organic acids (7.2%), bioactive peptides and carotenoids. These components not only improve palatability but also support stress tolerance, disease resistance and gut health. This corn protein complex also contains approximately 0.6% phytosterols, which help balance cholesterol levels when replacing fishmeal and optimises formulation costs. Expensive cholesterol supplementation in shrimp feeds is one of the major limitations of other fishmeal alternatives.

Since the product is derived from corn protein, it has a much lower carbon footprint than soybean sources. Shrimp have shown improved growth and survival rates when Motiv replaces fishmeal at inclusion levels up to 15%. It helps reduce pressure on natural resources and meet sustainability certification standards.

A limitation as a total fishmeal replacement

The only limitation of this corn protein complex when used to replace fishmeal is the lack of important fatty acids, despite having high levels of omega-6 PUFAs, i.e., linoleic acid. There are no important fatty acids, as those found in fishmeal, such as eicosapentaenoic acid-EPA, docosahexaenoic acid - DHA and arachidonic acid – ARA.

Therefore, replacing fishmeal with only Motiv requires combining ingredients rich in fatty acids (such as krill meal, seaweed or algae meal) or marine fish oil rich in omega-3s to provide these fatty acids (EPA, DHA and ARA) as well as add taurine, which is an amino acid abundant in fishmeal. Taurine plays an important role not only for palatability but in the regulation of osmotic pressure of farmed shrimp and marine fish in fluctuating salinity environments.

Combinations to produce functional feeds

As Motiv is a premium protein source containing several health nutrients, it can be combined with other premium protein sources (krill meal, high-quality fishmeal, yeast cell extract, seaweed and/or marine algae extract), organic minerals (especially organic selenium), and vitamins (A, E, C and D3) to produce functional feeds for shrimp.

Trials on replacing fishmeal or poultry meal in shrimp diets

The corn protein complex was tested and evaluated in several indoor and commercial pond trials at various inclusion rates as a replacement for fishmeal or poultry meal in diets for whiteleg shrimp (*Penaeus vannamei*). The results showed that 7.5% to 10% Motiv in the formula is the optimal inclusion level when replacing fishmeal in whiteleg shrimp feed.

Across the trials, shrimp showed improved growth, survival rates and feed conversion ratios (FCRs). Shrimp fed diets containing the corn protein complex for at least 60 days until harvest also developed a darker red colouration (1.0-1.5 points higher on the Salmo Fan to 25.5). In a trial, shrimp fed a commercial diet containing 50ppm astaxanthin showed a lighter red colouration than shrimp fed a diet with 7.5% Motiv and 25ppm astaxanthin. Motiv has 285ppm of carotenoids as xanthophylls. Therefore, we calculated that this reduced supplementation of astaxanthin in a shrimp feed formulation with 7.5% inclusion of the corn protein complex gave savings at USD20/tonne.

Tables 1-3 show shrimp performances with a typical approach of replacing either fishmeal or poultry meal in shrimp diets with the corn protein complex.

	Control	Treatment diets	
Main ingredients		Motiv 1	Motiv 2
Fishmeal1 (%)*	C	C	C
Fishmeal 2 (%)	8.00	4.00	0
MOTIV (%)	0	3.85	7.70
Fish oil & lecithin (%)	2.10	2.25	2.40
Parameters			
Average final weight (g)	8.13[a]	11.09[b]	11.24[b]
Average FCR	1.22[a]	1.21[a]	1.15[a]
Average survival rate (%)	91.17[a]	93.30a[b]	95.00[b]

Table 1. An 8-week feeding trial in RAS with whiteleg shrimp *Penaeus vannamei* where MOTIV™ replaced fishmeal. Initial shrimp weight was 1g and there were four replicates for control and dietary treatments. Values with the same superscript letters show no significant difference ($p > 0.05$).



*For confidentiality, C represents the percentage of fishmeal not replaced, as feed mills prefer not to disclose the total fishmeal inclusion rate.

	Control	Treatment diets			
Main ingredients		Motiv 1	Motiv 2	Motiv 3	Motiv 4
Fishmeal 1*	A	A	A	A	A
Fishmeal 2	16.5	14.5	12.5	10.5	8.5
Corn protein complex-MOTIV (%)	0	1.94	3.88	5.82	7.76
Cholesterol	0	0.06	0.12	0.18	0.24
Fish oil & Lecithin	2.1	2.2	2.3	2.4	2.5
Premix	1	1	1	1	1
Others, including A	80.4	80.3	80.2	80.1	80
Total	100	100	100	100	100
Parameters					
Initial weight (g)	1.7	1.7	1.7	1.7	1.7
Final weight (g)	11.53^{a}	11.51^{a}	11.45^{a}	11.30^{a}	11.48^{a}
Survival rate (%)	89.20^{a}	91.70^{a}	93.30^{a}	90.00^{a}	91.70^{a}
FCR	1.26^{a}	1.27^{a}	1.27^{a}	1.29^{a}	1.28^{a}

Table 2. An 8-week feeding trial in RAS with whiteleg shrimp *Penaeus vannamei* where MOTIV™ replaced fishmeal. There were four replicates for control and treatment diets. Values with the same superscript letters show no significant difference ($p > 0.05$).

*For confidentiality, A represents the percentage of fishmeal not replaced, as feed mills prefer not to disclose the total fishmeal inclusion rate.

	Control	Treatment diets		
Main ingredients		Motiv 1	Motiv 2	Motiv 3
Fishmeal (%)	15	7.5	0	15
Poultry meal (%)	10	10	10	2.5
MOTIV (%)	0	7.5	15	7.5
Krill meal (%)	3	3	3	3
Added cholesterol (%)	0.009	0.012	0.013	0.008
Added choline (%)	0.1	0.5	0.8	0.1
Soy lecithin (%)	1.2	1.6	1.8	1.8
Parameters				
Average final weight (g)	19.63^{ab}	19.84^{ab}	18.65^{b}	20.94^{a}
Average FCR	1.30^{ab}	1.39^{a}	1.21^{b}	1.26^{b}
Average survival rate (%)	81.80^{c}	87.27^{a}	86.80^{a}	82.40^{c}

Table 3. A 90-day trial in hapas within a commercial shrimp pond with whiteleg shrimp *Penaeus vannamei* where MOTIV™ replaced fishmeal and poultry meal. Initial shrimp weight was 0.61g. There were 10 replicates per dietary treatment and control. Values with the same superscript letters show no significant difference ($p > 0.05$)

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MOTIV™
a Cargill product



One powerhouse ingredient.

Motiv is much more than a protein alternative. It's a functional ingredient specially designed for shrimp nutrition. It improves nutrient utilization and uptake of the entire diet by creating a better environment in the gut. This leads to greater growth, improved stress and immune response, as well as a more vibrant color. Motiv delivers high-performance results. All from one ingredient.

More value. Healthier shrimp. That's Motiv
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Is stress limiting farm performance?

How do long-chain polysaccharides improve survival and efficiency?

By Alberto Saltó



Global aquaculture faces major challenges today. Among them are stressful situations caused by disease and climate change, which threaten the welfare of fish and shrimp and affect the profitability of your production. How can you deal with it? For a more resilient aquaculture, functional nutrition plays a decisive role.

The growth of aquaculture in recent decades has made it one of the most dynamic food sectors in the world, with unprecedented production levels and growing demand. However, this expansion is occurring against a backdrop of health, environmental and economic pressure. The increased prevalence of diseases, climate change, pollution and rising production costs are forcing the industry to seek solutions that guarantee productivity, animal welfare and sustainability.

One of the main challenges has been the physiological stress experienced by fish and shrimp in response to environmental changes or infections. The increase in water temperature, acidification, variations in environmental quality and alterations in microbial communities can favour the emergence of aquatic disease outbreaks.

Under these conditions, the animals divert a greater proportion of energy towards maintaining homeostasis and activating immune responses, reducing the resources available for growth and feed efficiency. Consequently, growth slows down, the feed conversion ratio worsens and the overall performance of the farm is affected.

Therefore, the industry needs nutritional tools that allow progress towards more efficient diets without compromising animal health. In this context, functional nutrition takes on a strategic role.

The key role of bioavailable free nucleotides

Beyond fulfilling basic needs, certain functional ingredients can help to strengthen the immune system, promote resistance to pathogens and improve production efficiency. Prominent among these are nucleotides, essential components of DNA and RNA that participate in key physiological processes, especially in tissues with a high cell turnover, such as the gut and immune system.

During periods of physiological stress, immunosuppression, infection or disease, the demand for nucleotides increases and the body may not be able to produce sufficient quantities. Dietary supplementation with free nucleotides can support cell turnover, contribute to gut health and release metabolic energy to maintain growth or recovery for other processes, such as the immune response or recovery from stress. A balanced immune system is essential for promoting antibacterial resistance, improving disease tolerance and sustaining the overall welfare of animals.

The role of long-chain polysaccharides in animal health

Beyond essential nutrients, certain long-chain polysaccharides of marine and plant origin act as key functional ingredients in shrimp nutrition. Among these, β-glucans, fucoidans and alginic acid stand out, recognised for their ability to modulate the immune response and help improve resistance to diseases.

β-glucans act as natural immunostimulants, activating innate defence mechanisms in shrimp, such as phagocytosis and haemocyte activity. For their part, fucoidans sulphated polysaccharides found in brown algae have antioxidant, anti-inflammatory and antimicrobial properties, helping to improve gut health and resilience against environmental stress and pathogens. Alginic acid promotes the integrity of the digestive tract and can act as a prebiotic, promoting a favourable microbiological balance.

Overall, the inclusion of these polysaccharides in the diet can enhance immunocompetence, improve survival and help optimise production performance, especially in intensive farming conditions where health and environmental challenges are high.

Building resilience to maintain feed efficiency

Nucleoforce® Immunity (Bioiberica, Spain) is a functional ingredient of natural origin, derived from yeast and algae, with a high concentration of bioavailable free nucleotides and long-chain polysaccharides that help activate the innate immune system. When incorporated in feed, it helps to improve resilience during adverse situations.

In the Pacific white shrimp *Litopenaeus vannamei*, several studies have shown that nucleotide supplementation can support immune response and survival during bacterial challenges and contribute to the profitability of the production system, even in diets where part of the fishmeal is replaced with plant proteins. Against pathogens such as *Vibrio parahaemolyticus* and *Vibrio harveyi*, positive effects on disease tolerance and resistance to aquatic pathogens were observed.

The contribution to production efficiency and survival made by a specific combination of free nucleotides and long-chain polysaccharides offers a potentially positive economic impact for the shrimp industry, optimising investment and yield.

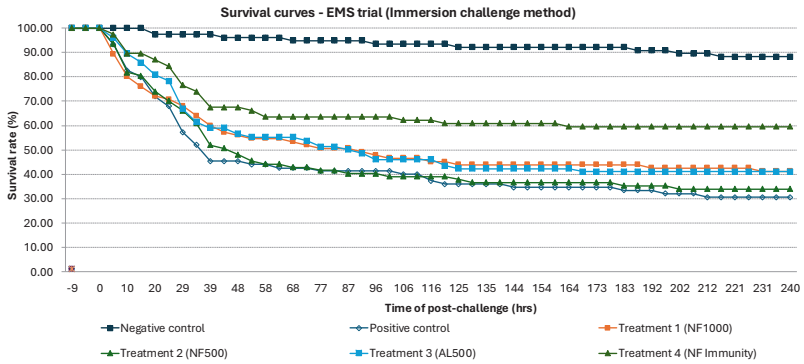


Figure 1. Survival rate of *Litopenaeus vannamei* after *Vibrio parahaemolyticus* (AHPND) challenge.

Ultimately, aquaculture needs solutions that combine productivity, health and sustainability. However, in a highly technological and optimised industry where every production variable is monitored, and every decision directly impacts margins, there is no room for unfounded proposals. The solutions that really drive adoption are those backed by solid scientific evidence, technical validation under real production conditions and consistent results in key indicators such as growth, survival, feed efficiency and return on investment (ROI).

In this context, aquaculture companies seek specialised providers that can demonstrate the value of their solutions through proven success stories and a deep understanding of their products' mode of action. Promises or trends are no longer sufficient: the industry expects rigour, traceable results and a measurable contribution to production efficiency. Thus, moving forward requires prioritising science-based innovations and return on investment and moving away from speculative approaches or those lacking validation. Thus, nucleotide supplementation is presented as a validated nutritional strategy to promote immunity, help improve performance, support gut health and facilitate the use of plant protein sources.

In a scenario marked by climate change, disease outbreaks and pressure on marine resources, building resilience through nutrition will be key to the industry's future.

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Preventive effects of a phytogenic additive against EMS, WFS and WSSV in white shrimp

Discover how preventive phytogenic nutrition can help strengthen shrimp resilience against diseases, while improving survival, feed efficiency and field performance under commercial farming conditions

By Stéphane Frouel, Niran Warin and Jérémie Potier

The rapid intensification of shrimp aquaculture has increased the emergence of complex pathological syndromes affecting intestinal function, growth and survival. Among them, early mortality syndrome/acute hepatopancreatic necrosis disease (EMS/AHPND), white faeces syndrome (WFS) and viral infections such as white spot syndrome virus (WSSV) remain major constraints in Asian production systems (FAO, 2013). These diseases are commonly associated with intestinal dysbiosis, epithelial damage, reduced nutrient absorption and secondary infections, leading to increased feed conversion ratio (FCR), higher mortality and significant economic losses. Conventional strategies based on antibiotics and disinfectants have limited long-term efficacy and are increasingly restricted by regulatory concerns and bacterial resistance issues (Zeng et al., 2024).

In this context, nutritional strategies aimed at strengthening host robustness and intestinal microbiota stability have attracted growing interest. Phytogenic additives, especially those with non-specific antimicrobial mechanisms and microbiota modulating properties, represent a promising alternative for disease prevention in shrimp. This article compiles results from several trials evaluating a phytogenic additive based on sulphur containing compounds (A-Live, Mixscience, France), designed for preventive modulation of the intestinal microbiota and enhancement of resistance in white shrimp.

Experimental tank trials (Thailand, 2016)

The experiment was conducted at Prince of Songkhla University (PSU) using 184L glass aquaria with a working volume of 130L, with constant aeration, 20% water exchange daily and monitoring of physicochemical parameters (salinity 25ppt, dissolved oxygen 5-6mg/L, temperature 27-28°C and alkalinity 100-120mg/L).

Pathogen-free post-larvae (PL5) with an initial weight of 0.885g were distributed at 1,000 individuals/aquarium into five treatments: an unchallenged control (PC), a challenged control (NC) and three challenged treatments containing respectively 1, 3 and 5kg/tonne feed of A-Live. Animals were fed five times/day for 20 days before challenge, with growth, feed intake, FCR, survival and size distribution recorded. Subsequently, challenges were performed with WSSV and *Vibrio parahaemolyticus*, the strain responsible for EMS.

WSSV challenge

At the end of the feed acclimation period (20 days), shrimp were randomly removed from each treatment to assess resistance to WSSV infection. Shrimp were immersed in a WSSV suspension at a concentration corresponding to the previously determined LD_{50}. Mortality was recorded for 14 days after challenge. Challenge related mortality was confirmed by PCR analysis.

Challenge with Vibrio parahaemolyticus

Similarly, after feed acclimation, shrimp from each treatment were subjected to a resistance test against *V. parahaemolyticus* infection. A bacterial suspension of *V. parahaemolyticus* was prepared from an 18-24 hours culture and adjusted to reach a final concentration of approximately 10^6 CFU/mL in the culture water. After exposure, shrimp were returned to the culture tanks and mortality was recorded for 14 days.

Large scale field monitoring (Vietnam, 2019)

A total of 254 commercial ponds were monitored under standard production conditions. The additive was applied preventively at 3g/kg of feed, with no parallel control group. The incidence of EMS, WFS and WSSV, as well as mortality occurrence, was recorded during the first 45 days of culture.

Commercial field trials (India, 2019)

Four independent trials were conducted on farms affected by WFS. Two application strategies were evaluated:

- Preventive use: continuous supplementation at 3kg/tonne feed from early stages.
- Curative use: supplementation at 5kg/tonne feed initiated after the onset of severe WFS signs.

Growth parameters, total biomass, FCR, survival rate and commercial quality criteria at harvest were evaluated.

Preventive effects under experimental challenges

In the tank trials conducted in Thailand, supplementation with A-Live did not produce significant differences in growth parameters or feed efficiency in *Penaeus vannamei* post-larvae. Over the 20-day period, variations in feed intake among treatments were minimal. Final weight, weight gain, feed intake and survival values remained within ranges like the control, with survival rates of 63-68% and no statistical differences ($p > 0.05$) (Tables 1 and 2).

Treatments	Average weight (mg/shrimp) Day 0	Shrimp number Day 0	Total length (mm) [n=100/group] Day 0	Average weight (mg/shrimp) Day 20	Shrimp number Day 20	Total length (mm) [n=150/group] Day 20
Controls [PC+NC]	0.885[a]	1,000 ± 3[a]	5.2 ± 1.0[a]	32.4 ± 1.9[a]	632 ± 78[a]	18.58 ±.9[a]
NC + A-Live 1 kg/t	0.885[a]	1,002 ± 3[a]	5.2 ± 1.1[a]	32.6 ± 2.3[a]	662 ± 93[a]	18.54 ± 1.9[a]
NC + A-Live 3 kg/t	0.885[a]	999 ± 1[a]	5.2 ± 1.0[a]	34.2 ± 1.1[a]	682 ± 6 9[a]	18.57 ± 1.5[a]
NC + A-Live 5 kg/t	0.885[a]	1,000 ± 3[a]	5.2 ± 1.1[a]	32.6 ± 5.6[a]	664 ± 103[a]	18.10 ± 1.7[a]
Control group: mean ± standard deviation of eight replicates. Treated groups: NC + A-Live 1 kg/t feed, NC + A-Live 3 kg/t feed, NC + A-Live 5 kg/t feed. Data are presented as mean ± standard deviation of five replicates. Mean values not sharing the same superscript letter are significantly different ($p < 0.05$).						

Table 1. Average weight, number of shrimp and total length of post-larvae after 20 days of feeding with the experimental diet and before challenges.

Treatments	Weight gain (mg/shrimp)	Average daily gain (mg/shrimp/day)	SGR (%/shrimp/day)	Survival (%)
Controls [PC+NC]	31.5 ± 1.9[a]	1.57 ± 0.09[a]	6.78 ± 0.54[a]	63.1 ± 7.8[a]
NC + A-Live 1 kg/t	31.7 ± 2.3[a]	1.58 ± 0.11[a]	6.72 ± 0.56[a]	66.0 ± 9.2[a]
NC + A-Live 3 kg/t	33.3 ± 1.1[a]	1.66 ± 0.05[a]	6.48 ± 0.19[a]	68.2 ± 6.9[a]
NC + A-Live 5 kg/t	31.7 ± 5.6[a]	1.58 ± 0.28[a]	6.80 ± 1.17[a]	66.4 ± 10.3[a]
Control group: mean ± standard deviation of eight replicates. Treated groups: NC + A-Live 1 kg/t feed, NC + A-Live 3 kg/t feed, NC + A-Live 5 kg/t feed. Data are presented as mean ± standard deviation of five replicates. Mean values not sharing the same superscript letter are significantly different ($P < 0.05$).				

Table 2. Growth performance and survival of shrimp post-larvae after 20 days of feeding with the experimental diet and before challenges.

The most notable effects of the phytogenic additive were observed in disease resistance: preventive supplementation with the phytogenic additive significantly reduced cumulative mortality following EMS and WSSV challenges (Figures 1 and 2). However, the challenge tests showed robust effects on pathogen resistance. Upon exposure to *V. parahaemolyticus*, mortality decreased in a dose-dependent manner, from 87% in the negative control to 45%, 33.3% and 30% in the treatments containing 0.1%, 0.3% and 0.5% of A-Live, respectively.

A similar pattern was observed against WSSV, with significantly lower mortality rates (37-25%) in supplemented treatments compared with the control (82%).

Commercial scale validation

Large-scale monitoring in Vietnam showed that 74.4% of ponds, all treated with the additive at 3kg/tonne feed, did not show significant mortality during the initial production phase (Figure 3). Only 15% of ponds showed mortality associated with EMS, while WFS and WSSV incidences remained below 5%. These values are substantially lower than those usually reported in intensive shrimp production systems. EMS is normally present in 30-40% of stocked ponds and affected ponds may show 30-80% mortality.

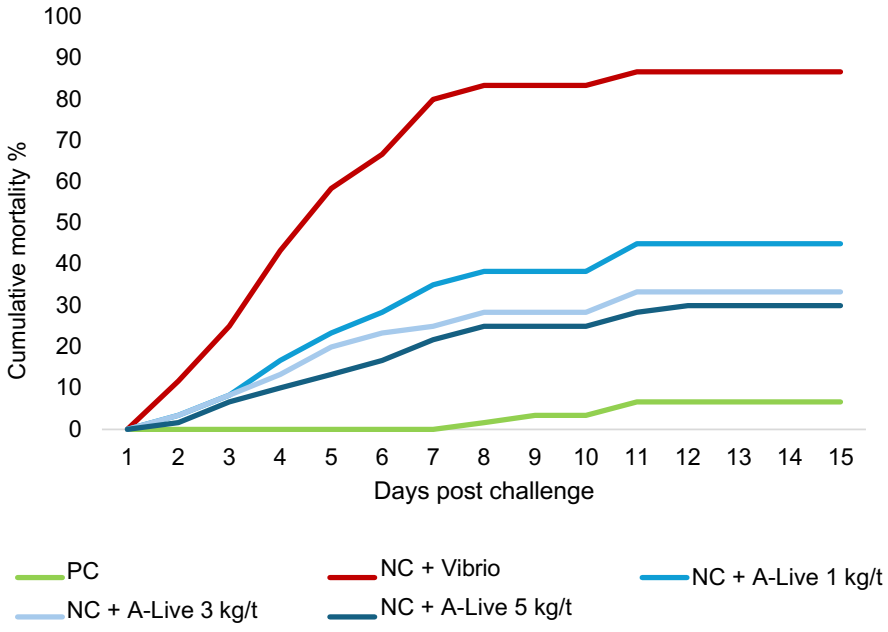


Figure 1. Cumulative mortality after EMS challenge.

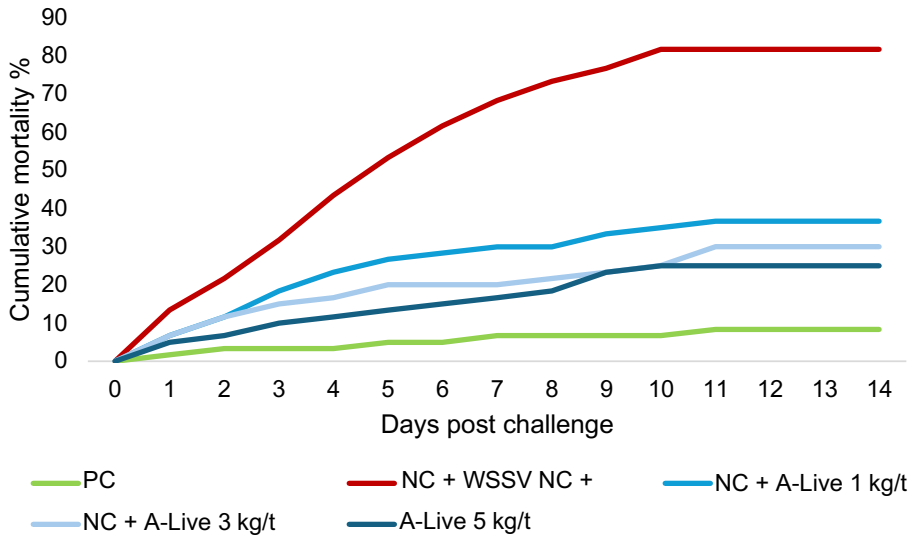


Figure 2. Cumulative mortality after WSSV challenge.

Comparison between preventive and curative use

In the three trials conducted in India, preventive application of the product at 3kg/tonne feed significantly improved zootechnical performance. WFS is typically observed in 15-40% of ponds per cycle in India. Affected ponds generally show 10-30% mortality, with the main impact being delayed growth and increased FCR. WFS is also associated with poor shell quality (soft shell, weak exoskeleton) and may reduce quality after cooking.

Ponds treated with A-Live showed higher individual final weight, greater harvested biomass, reduced FCR and increased survival compared with controls, with no negative effect on commercial product quality. Although shrimp receiving this phytogenic additive appeared visibly darker before processing, cooked shrimp from both control and treated ponds were classified as A2, indicating an acceptable commercial colour and cooking quality under the grading system used by the processor. This suggests that the darker raw pigmentation observed in treated shrimp did not translate into any downgrade in cooked product appearance or marketability (Table 3).

In contrast, curative application (trial 4) of the product at 5kg/tonne feed after the onset of WFS helped limit syndrome progression and reduce clinical severity, although recovery of growth and feed efficiency was only partial. This result is consistent with studies indicating that established intestinal damage and dysbiosis are difficult to fully reverse (Zeng et al., 2024; Xu et al., 2025).

Implications for health management

The differences observed between preventive and curative strategies reflect the underlying pathophysiology of EMS and WFS. Our results suggest that early prevention of intestinal dysbiosis limits the cascading effects associated with EMS and WFS, explaining the greater efficacy of preventive strategies compared with curative ones. The non-specific antimicrobial action of phytogenics, together with their capacity to preserve functional microbial biodiversity, appears to play a key role in maintaining long-term intestinal resilience (Zeng et al., 2024; Xiong et al., 2024).

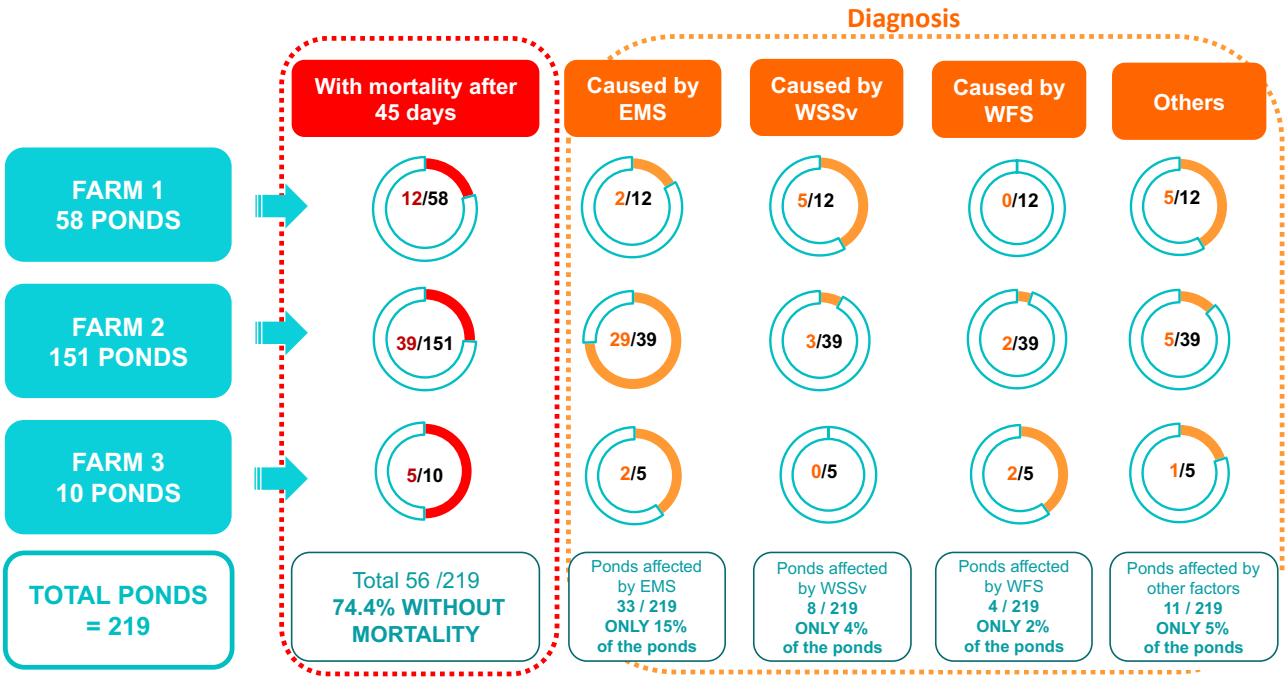


Figure 3. Mortality observed across all ponds and associated epidemiological causes.

	Trial 1		Trial 2		Trial 3	
Parámetro	**Control**	**A-Live 3kg/t**	**Control**	**A-Live 3kg/t**	**Control**	**A-Live 3kg/t**
Average body weight (ABW in g)	17.9	19.3	24.9	20.2	17.5	18.9
Total biomass (kg)	NA	NA	3,007	3,378	2,333	2,921
FCR	2.12	1.68	1.85	1.59	2.37	1.91
Survival (%)	63%	84%	88.91%	90.46%	61.7%	752%
Cooking quality	NA	NA	A2	A2	A2	A2
Note: A2 refers to the commercial cooked-shrimp colour/quality grade used during the field evaluation. As grading scales may vary between processors or markets, this classification should be interpreted as an indicator of acceptable market quality within the local assessment system.						

Table 3. Growth performance, survival and cooking quality of shrimp in commercial field trials.

Conclusion

The comparison between the controlled trial conducted in Thailand and the field studies carried out in Vietnam and India provides a broader and deeper understanding of the efficacy of A-Live in health management and in optimising the productive performance of *P. vannamei*. Although these studies were conducted under different epidemiological and operational contexts, their results converge on one essential point: the product exerts a decisive effect on antibacterial resilience and intestinal integrity in shrimp, establishing itself as a strategic tool for production systems exposed to high pathogen pressure.

Under the controlled conditions of the Thai experiment, the absence of effects on growth or feed conversion confirms that our phytogenic additive does not act primarily as a growth promoter, but rather as a specific modulator of the intestinal microbiota. The results demonstrate a significant improvement in resistance against two highly virulent pathogens — *V. parahaemolyticus* (EMS/AHPND) and WSSV — with survival increases reaching four to five times the control levels. This statistically robust and dose-dependent effect suggests activation of innate defence mechanisms, such as reinforcement of the epithelial barrier, stimulation of antimicrobial responses or regulation of inflammatory processes.

The data generated in India complement this understanding by providing evidence of how these mechanisms translate into real farming conditions, where shrimp face multifactorial, dynamic and often difficult to diagnose pathogens. In the case of WFS, a complex condition associated with intestinal dysbiosis, epithelial alterations and metabolic disturbances, A-Live demonstrated notable operational efficacy, with rapid disappearance of clinical signs, improved FCR, increased survival and higher final biomass. The fact that these results were observed in both preventive and curative applications highlight the functional versatility of the product in demanding production environments.

Overall, the integration of both studies shows that this phytogenic additive constitutes a complete biofunctional solution, supported by solid experimental evidence and validated by field results. The Thai study provides mechanistic foundations for its protective effect against highly virulent pathogens, while the Indian trials reveal its systemic impact on intestinal health and productive efficiency, which are critical factors for intensive cultures highly sensitive to health imbalances.

Thus, A-Live is positioned as a strategic innovation for the sustainability of shrimp aquaculture, capable of reducing health risks, stabilising performance and contributing to the profitability of production systems. In a context where emerging diseases and microbiota disorders represent growing challenges for the global industry, the product is established as a key resource to strengthen the resilience of farming systems, both in controlled environments and under real production conditions. The compiled results indicate that preventive inclusion of the phytogenic additive consistently reduced mortality associated with EMS, WFS and WSSV, with concomitant improvements in survival and feed efficiency under both experimental and commercial conditions.

Although curative application may mitigate disease severity, these results position phytogenic-based preventive nutrition as a strategic pillar of modern shrimp health programmes. These findings support the integration of functional phytogenic additives into sustainable health and biosecurity programmes in shrimp aquaculture.

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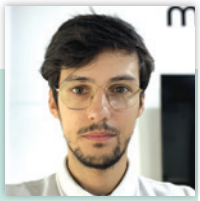
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Scaling methane-based protein for aquafeeds

As the aquaculture and animal nutrition industries search for sustainable alternatives to fishmeal, methane-based single-cell proteins are gaining renewed attention.

By Zuridah Merican

Unibio is a Danish technology company built around a fermentation process whose scientific origins stretch back several decades. In 2001, the company was set up specifically to industrialise the technology using a vertical loop fermenter. This marked the start of the modern U-Loop® fermentation process as a commercial platform. Unibio's single-cell protein, Uniprotein®, is produced through methane fermentation using the naturally occurring bacterium *Methylococcus capsulatus*, one of the few bacteria used commercially that rely on methane as their main source of energy.

A conversation with Olivier Hartz, CCO, Unibio

After a stint consulting for Unibio, Olivier Hartz joined the company in June 2024. This is after spending 21 years with the Ajinomoto Group with exposure to various aspects of animal nutrition. Today, as its Chief Commercial Officer, Hartz is responsible for the global commercialisation of Uniprotein across its target markets. Now with regulatory approvals in multiple markets and a 50,000 tonne production facility under development in Saudi Arabia, the company is entering a new phase of commercial scale-up. Over coffee in Strasbourg, France, Hartz discussed Unibio's marketing strategy, the company's expansion plans as it moves from start-up to scale-up and highlighted recent opportunities for alternative meals amid rising fishmeal prices.

Regulatory approvals open global opportunities

Can you elaborate on the current regulatory status and target markets for Uniprotein?

We have already secured regulatory approvals in ten markets and territories, although the scope of authorisation varies by country. We now have full-scope approval covering animal feed, aquaculture and pet food across the EU and EEA, UK, Chile and India. Japan has approved the product for aquaculture and pet food, while Thailand and Russia have approved it for animal feed and aquaculture. Saudi Arabia and the US currently authorise it specifically for aquaculture applications, with the US approval covering salmon at all stages of farming.

Current commercial focus is centred on aquaculture species, particularly carnivorous fish such as seabream, seabass, yellowtail, barramundi, trout and salmon, as well as shrimp and weaned piglets. Targeting trout is obvious, particularly as the factory will be in Saudi Arabia, and the largest trout producer close by is Türkiye.



Olivier Hartz is CCO at Unibio

Aquaculture remains the primary target market

What percentage of your business do you expect to come from each product segment?

While we see opportunities across several animal nutrition sectors, aquaculture is expected to account for the majority of future demand, mostly for carnivorous fish. Aquafeed will take the lion's share of our initial volumes. The combination of carnivorous fish and shrimp represents our primary market.

Weaned piglets are a very concrete next step for us. We have solid data supporting the application. From Saudi Arabia, we are well placed to serve demand in the Philippines, Taiwan and Thailand. Pet food is another attractive market, particularly in premium formulations, where methane-based single cell proteins are considered low-allergenic ingredients. In addition, it is classified as a non-animal-origin ingredient.

Further ahead, Unibio is exploring opportunities in human nutrition. However, that remains a longer-term objective as the company progresses through novel food safety studies and regulatory submissions.

Saudi Arabia becomes the centrepiece of global expansion

Unibio recently announced a joint venture to build a single-cell protein plant in Jubail, Saudi Arabia. What is the current status of this project?

Yes, we signed the joint venture with the Saudi Industrial Investment Group (SIIG), to build a single-cell protein plant in Saudi Arabia, in an 80:20 split (SIIG:Unibio). The first phase will deliver 50,000 tonnes annually, making it the world's largest single cell protein production facility. Long-term plans envisage expansion beyond 300,000 tonnes per year.

The Saudi project builds directly upon lessons learned from Protelux, our licensed production facility in Ivangorod, Russia. Protelux was the first industrial-scale U-Loop® facility ever built, with a 6,000-tonne single module. The operational experience gained there has been fully incorporated into the design of the Saudi facility. However, geopolitical developments since 2022 have shifted the company's strategic focus away from Russia. Our commercial scale-up strategy is now firmly centred on the Middle East.

Scale and location drive competitiveness

A key question surrounding alternative proteins is cost competitiveness. How will your BSCP (bacterial single-cell protein) be priced?

The Saudi facility is designed specifically to achieve the scale necessary to compete directly with conventional protein ingredients. Unit economics improve significantly at this scale. The Saudi plant operates at the point where costs shift decisively in our favour. Saudi Arabia offers methane and energy at regulated prices that are structurally below international market rates. Further expansion would improve economics even more, as major investments in utilities and engineering infrastructure would not need to be duplicated.

The result is that we can compete against all major high digestibility protein ingredients, including fishmeal, soy protein concentrate, wheat gluten, blood products and potato proteins. Another differentiator is pricing stability. We can offer customers multi-year, firm pricing commitments, something extremely difficult for conventional protein sources whose costs fluctuate with harvest cycles, fisheries and commodity markets.

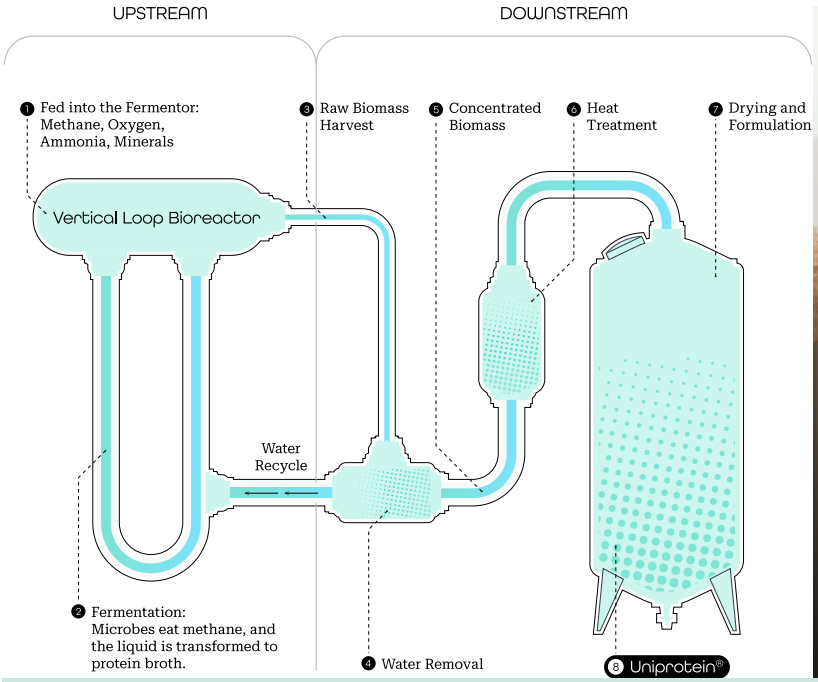
Performance in fish and shrimp

You've conducted research and development on marine fish and shrimp at KAUST (King Abdullah University of Science and Technology) and other institutions. What results stand out when using this BSCP as a fishmeal or soymeal replacement, and how does it perform on palatability?

Yes, we have participated in research with institutions including KAUST, and under the SUPIAF (Sustainable Protein Ingredient for Animal Feed) project, a Danish-led European initiative designed to tackle the EU's heavy reliance on imported soy and fishmeal. Together they have generated encouraging results across multiple aquaculture species. We consistently see a sweet spot at inclusion rates between 5-10%. At those levels, Uniprotein delivers a double benefit: it replaces a high-quality protein ingredient while providing additional functional value.

We conducted digestibility studies in barramundi and measured protein digestibility at 88%. Aarhus University in Denmark measured digestibility at approximately 85% in trout and slightly above 85% in salmon.

Additional trials include seabream, and ongoing seabass work with IRTA in Spain using SPAROS diets, shrimp studies with IMAQUA in Belgium and IRTA, and a joint shrimp trial with Lucta (Figure 1). The Lucta trial found that 10% inclusion improved growth without needing a palatant, while 20% inclusion reduced feed intake, which was partly restored by a palatant. In fish, palatability is generally not an issue except for naturally selective species such as seabass.





Unibio's process of converting methane into Uniprotein®, an alternative to traditional protein sources.

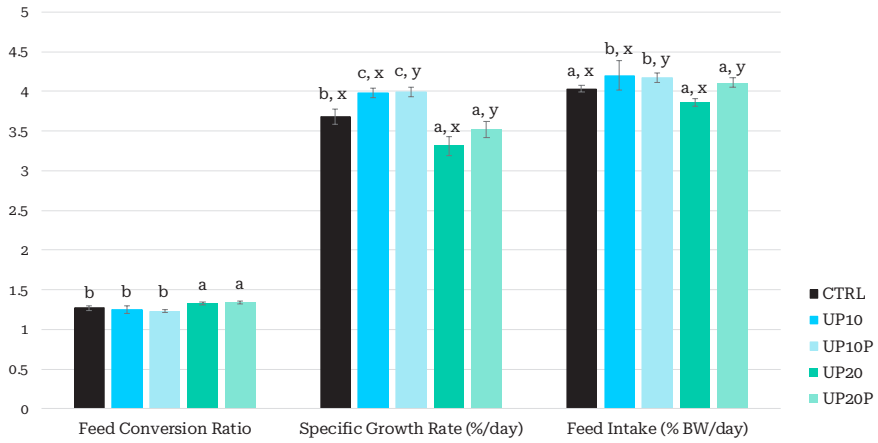


Figure 1. A growth trial was carried out with white shrimp *Litopenaeus vannamei* at Riasearch (SPAROS Ltd.). Growth increased with 10% Uniprotein® in the diet (48% fishmeal replacement). It decreased at 20% Uniprotein®, but this was offset by adding a palatant (Luctamax®, LUCTA, S.A.).

Consistency represents another important advantage compared with fishmeal. Uniprotein comes from a controlled fermentation process, which means every batch is highly consistent. The product also avoids many challenges associated with plant proteins.

How broad is your species database today?

We have evaluated trout, salmon, seabream, shrimp, seabass, barramundi, sturgeon and European catfish. Seabass is naturally one of the more challenging species from a palatability standpoint, but that is not unique to Uniprotein. We consistently observe lower mortality, reduced morbidity and improved growth at our recommended inclusion rates. For Asia Pacific, our immediate priorities remain shrimp and carnivorous marine fish.

We have compiled about 85 papers on *Methylococcus capsulatus* biomass, roughly 45 of them in aquaculture, enabling inclusion rate guidance for carnivorous fish based on internal and external studies. Most data relate to grow-out stages rather than all life stages. This enables us to tabulate the % inclusion rates for several species based on our work as well as that of other SCP producers.

Expanding across Asia

For Asia, do you anticipate any market entry constraints?

Although regulatory requirements vary among countries, we do not see major barriers to market entry. As a feed ingredient, the regulatory pathway is generally manageable. Every country has its own process, but these are not insurmountable challenges. Indonesia and China are expected to require somewhat longer approval timelines due to additional regulatory requirements. Vietnam presents a different challenge. The key issue there is selecting the right importer and commercial partner. To support regional expansion, we expect a combination of distributors and direct customers to provide the most effective route to market.

Expected demand with rising fishmeal prices

Now that fishmeal has risen to around USD1,800 per tonne, does this create new opportunities for single-cell protein and insect meal producers?

Yes, fishmeal prices have increased substantially, creating renewed interest in alternative proteins. With fishmeal trading closer to USD2,000 per tonne, the conversation becomes much easier. Our strategy remains the same. We compete on nutritional quality, consistency and total cost of inclusion, not simply price per tonne.

Does this open new opportunities for us? Yes, the price enables the discussion. It is much easier than a year ago when we introduced ourselves as a fishmeal substitute. The reality of our pricing system is that, whatever the fishmeal price, we are able to fix an index to it. We can offer a fixed price for two years, because our gas price in Saudi Arabia is fixed.

"The goal is for nutritionists to keep Uniprotein in the formulation because the data supports it, not because fishmeal happens to be expensive at a particular moment."

A long-term commitment to protein ingredients

Do you see your product remaining as a replacement ingredient, or could it eventually become a strategic ingredient in its own right for shrimp and marine fish feeds?

Today, we position Uniprotein primarily as a protein ingredient and fishmeal replacement. The product contains approximately 68% crude protein, of which 62.5% consists of amino acids. The functional benefits come second. However, I believe users will eventually discover additional value beyond protein nutrition. Our objective is not simply to replace fishmeal during periods of high prices. The goal is for nutritionists to keep Uniprotein in the formulation because the data supports it, not because fishmeal happens to be expensive at a particular moment.

We know functional properties are present. Customers may observe them when they use the product, and they will probably appreciate them because they come almost for free alongside the protein value. They observe benefits that encourage them to maintain a stable inclusion level rather than constantly adjusting rates based solely on raw material prices. Users simply need time and practical experience to recognise it.

Fishmeal is often described as a strategic ingredient that feed formulators are reluctant to remove completely. How will you address this?

We need to be realistic about scale. Fishmeal production is a global industry with five to six million tonnes of fishmeal being produced annually. When our Saudi facility starts operating, the volume may supply a handful of major customers but not the entire industry. What typically happens is not a complete switch from one ingredient to another. Feed formulators tend to adjust inclusion levels according to economics rather than eliminate ingredients altogether. For example, in Thailand's piglet feed industry, when fishmeal prices

are low, inclusion rates may increase to around 6%. When fishmeal prices rise, inclusion rates may drop to 2–3%. However, fishmeal is rarely removed completely because nutritionists feel there is still value in keeping some level in the formula. The same principle could eventually apply to Uniprotein.

You talked about side benefits from bacterial membranes and the nucleic acid as a source of nucleotides in fish. Does this mean that you are also seeking to market this BSCP as a functional additive at lower inclusion rates?

Uniprotein contains significant levels of nucleic acids, which can serve as a source of nucleotides and small peptides. Fish can derive the same benefits from nucleic acids because they break them down into nucleotides during digestion. When fishmeal is reduced, you need to pay attention to maintaining adequate nucleic acid levels because they play an important role in the stress response, gastrointestinal integrity and the immune system.

In the future there may be opportunities to fractionate the biomass and separate out specific components. At that point, we could potentially market functional fractions independently from the protein fraction. However, today, we are not marketing our BSCP as a low-inclusion functional additive. Admittedly, we could potentially position it as a functional ingredient, but then, you do not build a 50,000 tonnes/year factory simply to sell the benefits of bacterial cell membranes. That would only be a few-thousand-tonne business.

Who do you consider your main competitors?

You can consider all alternative protein technologies as competitors. Examples include companies working with bacterial proteins, insect proteins and other single-cell protein technologies. There are also companies that produce microbial biomass as a by-product of their industrial processes. But ultimately our real competition is conventional protein ingredients: fishmeal, soy protein concentrate, wheat gluten and other established protein sources used in feed formulations. That is where the market volume is.

Non-GMO by design

Finally, people might ask whether your BSCP is genetically modified. What is your response?

The *Methylococcus capsulatus* used by Unibio is a wild-type, naturally occurring bacterium. It is non-GMO. Uniprotein is produced through a natural fermentation process without any genetic manipulation. We have no intention of moving towards genetic modification because biomass production is fundamentally different from precision fermentation.

In precision fermentation, you can engineer a microorganism to produce more of a specific molecule by increasing expression of a particular gene. That approach works well when your objective is a single target compound. Our objective is different. We are producing biomass itself. For us, there is still significant potential through strain selection and process optimisation without introducing genetic modification.



Nutrition 3.0: Programming resilience and sustainability

Precise nutrition, together with functional ingredients, aim and correct certain targeted physiological functions during stressful events - with examples from tilapia and vannamei shrimp farming

By François Jegou

It is well established that aquaculture has been the fastest expanding food production sector globally for the last 50 years, growing at an average of 5.3% per year since 2000 (Dongyu Qu, FAO, 2021). However, this success story, behind its almost tranquil image, hides a more complex reality, just like with any other animal production industry.

Fish and shrimp farmers are continuously challenged by daily realities including multiple complexities frequently associated with infectious pathogens - primary or opportunistic. On top of this, water – and its constant variations in basic physicochemical characteristics such as dissolved oxygen (DO), ammonia, nitrite, temperature, pH, etc. can sometimes be challenging for an aquaculture producer to continuously monitor and especially to control. These are sources of stress which directly impact the economics and survivability of any aquaculture activity.

Moreover, increasing societal pressure for environmentally responsible and sustainable practices with regards to natural resources, together with rising raw material prices, lead to increasing ingredient substitution, the limits of which are constantly being pushed further.

However, nature's balance is more easily endangered when approaching its limits. At the farm level, approaching or surpassing these limits often brings long term hazardous consequences which may lead to overuse or misuse of antimicrobials and eventually to resistance occurrences. The World Health Organization (WHO) has identified antimicrobial resistance (AMR) as one of the top global public health threats, estimating that it was responsible for 1.27 million deaths in humans in 2019 alone, (GRAM, University of Oxford, 2022).

Regarding health management and optimisation, numerous studies in the field of stress assessment in aquaculture systems show the way to better address and manage aquaculture production with a new paradigm: reducing stress at all levels and stages. Having said that, continuously and increasingly facing challenges from all sides, aquaculture producers often find it difficult to prioritise cost and labour-effective actions which may guarantee better resilience and development of their production units.

"..a key tool might play an increasing role in providing help and comfort to the producer's daily challenges: nutrition, and more precisely, functional nutrition."

Adding investments and efforts in improved farm management and biosecurity practices, as well as rationalising health management, a key tool – nutrition or more precisely functional nutrition - might definitely play an increasing role in providing help and comfort to the producer's daily challenges.



Functional nutrition

Between precise nutrition and medication, there are ways that have proven to improve the physiology, the immunity -in its broad meaning, not only at the defence cells level- and the overall readiness of the organism confronted to different stresses.

These tools provide help by boosting specific physiological functions that are affected during stressful periods. Combining different tools improves the overall organism preparedness, thus its resilience. They do not have a direct role on any pathogen as in medicine. They do not lead to resistance occurrence. Therefore making them sustainable and environmentally friendly. Moreover, improving by natural means the organism's resilience naturally leads to improved and consolidated zootechnical performance. Consequently, this leads to improved farming profitability and resilience.

Below are some examples of utilising functional nutrition to enhance the resilience of fish and shrimp during common stressful events.

Oxidative stress and oxygen

Oxidative stress may be encountered in most farming operations worldwide at all life stages. However certain events can increase the physiological disbalance, for example with varying DO values. A comparative test conducted over two months on tilapia reared in cages in ponds at the ADM Research facilities in Brazil showed highly improved growth (+22%) and FCR (-14%) on fish fed with the DiOx blend compared to a control diet (Table 1). DO values in the ponds varied highly, but not unusually, from 1mg/L in the morning to 12.4mg/L in the afternoon.

Considering the worldwide and huge importance of such conditions related to low, varying, unknown or unmonitored oxygen levels in water, these results are more than promising with regards to ways to help producers in their daily operations globally. They lead the way to compensating for one of the most widespread bottlenecks in aquaculture performance and resilience.



ADM facilities in Aparecida do Taboado, Mato Grosso do Sul, Brazil.

Averages	Time	Temperature (° C)	Dissolved oxygen (mg/L)
Minimum	07:00	26.0	1.0
Maximum	16:40	34.3	12.4

Streptococcus



Streptococcosis is a worldwide infectious disease that may severely affect livestock production such as in swine. In aquaculture, many species can be affected by this bacterium, either in tropical or cold water, marine or freshwater. Tilapia production in particular can be seriously impacted during its whole production cycle. Episodes with late mortalities, up until harvest and even at above 1kg body weight, are not uncommon. Ways of prevention and treatment include vaccination and the use of antibiotics respectively, where specificity and resistance occurrence may lead to varying efficacies.

Most tilapia producers worldwide, however, have noticed the impact of environmental conditions such as temperature on Streptococcosis occurrences. Tilapia producers will reduce or even stop feeding when water temperatures rise to too high levels; therefore, feeding behaviour and typical signs of infection need to be monitored closely. Similarly, there is a trend to reduce fish density in rearing cages and to increase space between cages, in order to decrease infection pressures.

Vibriosis

Acute hepatopancreatic necrotic disease (AHPND), also known as early mortality syndrome, and more generally vibriosis constitute the number one bacterial threat to the shrimp industry. They may happen either at the early or at grow-out stages, in an acute or chronic pattern, affecting survival and growth performance. Current strategies to mitigate their impact include enhancing post larvae quality and care, biosecurity, water quality management, and of course antimicrobials, where extensive or inappropriate use may lead to the risk of resistance occurrence.

Setting the microbiota into action

Beyond its primary function in digestion, the intestine plays a fundamental role in immunity. Indeed, besides direct inhibition, fish gut microbiota plays essential functions in epithelial renewal and maturation, which in turn regulate immune responses (Gomez & Balcazar, 2008; Wang et al., 2017). Both activities are intrinsically related via the resulting microbiota, their maintenance, and optimisation.

As the intestine remains one of the most important pathogen portals of entry, this constitutes a critical point of interest and emphasises the importance of the digestive status and optimisation, through precise nutrition and specific functional ingredients. For example, strategies involving activated clay-based

Parameter	Control	DiOx	Difference %	p-value
Initial weight (g)	63.23	63.18	-0.08%	0.913
Final weight (g)	260.7[a]	303.46[b]	+16.4%	0.001
Average weight gain (g)	197.47[a]	240.28[b]	+21.68%	0.001
Biomass gain (kg)	11.94[a]	13.89[b]	+16.33%	0.001
Feed intake (kg)	19.02	19.04	0.11%	0.961
Feed conversion ratio (FCR)	1.59[a]	1.37 [b]	-14.05%	0.02

Table 1. Feeding the DiOx blend to tilapia over two months considerably reduced the negative impacts of oxidative stress related to low and varying dissolved oxygen in water.

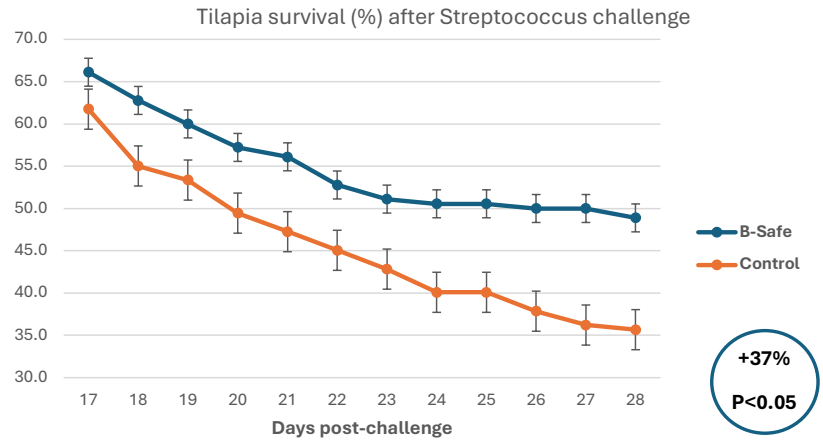


Figure 1. Tilapia survival (%) after Streptococcus challenge. Tilapia fed with the feed additive B-Safe (ADM) over 4 weeks and challenged with *Streptococcus agalactiae* gave a significant 37% higher survival rate ($p<0.05$) than the control.

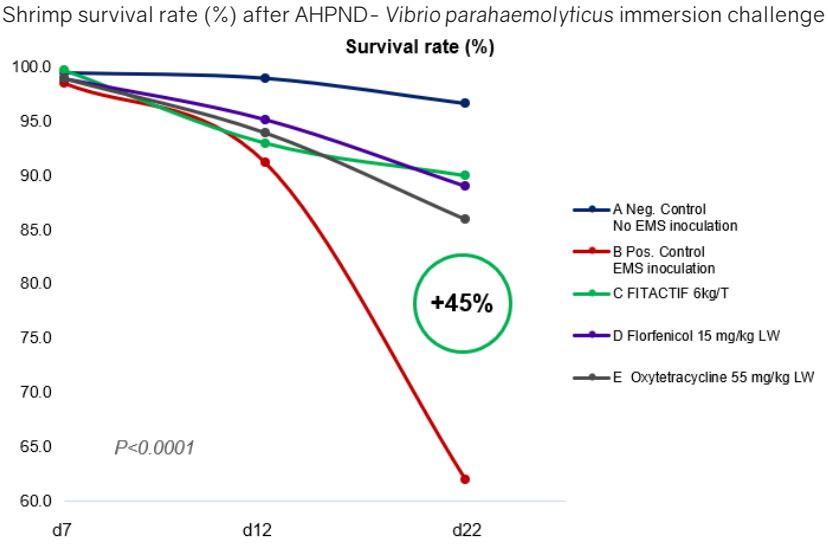


Figure 2. Shrimp survival rate (%) after AHPND- *Vibrio parahaemolyticus* immersion challenge. Shrimp *Litopenaeus vannamei* fed a diet with FITACTIF (ADM) over 3 weeks, resulted in an increased 45% ($p<0.0001$) survival after an AHPND-*Vibrio parahaemolyticus* immersion challenge

compounds favouring firmicutes populations while reducing proteobacteria, or blends of selected weak and strong organic acids working in a synergistic relay manner, both allow to stabilise the gut microbiota. Doing so, they reduce chances for the multiplication and colonisation of noxious organisms, and optimise gut activities to promote immunity, health and performance.

For instance, B-Safe, a patented specialty additive made from activated clay and plant extracts, allowed for a significant 37% higher survival rate ($p<0.05$) in tilapia when fed with this feed additive, 4 weeks after exposure to a *Streptococcus agalactiae* challenge test (Figure 1).

Similarly, FITACTIF, a blend of 10 short and medium-chain fatty acids incorporated in feed resulted in 45% significant increase ($p<0.0001$) in survival rate in shrimp three weeks after being exposed to an AHPND-*Vibrio parahaemolyticus* immersion challenge (Figure 2). Although it is not an antimicrobial, the result with this compound was similar to those obtained in the same test with florfenicol and oxytetracycline, two widely used antibiotics in aquaculture worldwide.

Nutrition 3.0: Accompanying modern aquaculture forward

Along with better farm management and preventive practices, functional feeding sets the way forward in reducing stress at all levels, optimising performance and resilience, and securing farm sustainability and economics.

From its primary role in fuelling growth, the aquafeed industry has progressively evolved to precisely meeting nutritional requirements at different life stages for fish and shrimp. Concurrently, it is adapting to necessary raw material substitutions to reduce the reliance on fishmeal and fish oil globally.

Functional ingredients are now added to precise nutrition to aim and correct certain targeted physiological functions to better prepare the organisms for stressful events. This approach is more critical and in demand in modern aquaculture than ever. It provides additional help to cultured populations that are constantly subjected to multiple threats and stresses, in environments where the acceleration in international trade with its complexities, is gradually setting new domestic rules including prices. This comes with increasing societal pressures on environmental concerns, and a rising global threat and awareness on antimicrobial resistance.

References are available upon request



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How the next generation is reshaping Southeast Asia's tilapia industry

On 27 January in Cebu, 46 young shrimp and tilapia farmers from the Philippines met peers from Indonesia and Thailand. The meeting was part of a U.S. Grains & BioProducts Council (USGBC) program to empower the next generation of aquaculture farmers across Southeast Asia. Perspectives on shrimp farming in Thailand, Indonesia and the Philippines were covered in the March/April edition (https://issues.aquaasiapac.com/view/520021778/12/).

In this article, we share insights from three young tilapia farmers on how they are contributing towards improving the strained tilapia industry in Southeast Asia.

- **Hector S. Abes** and **Carlo Enrico A. Latonio** from the startup, Kaizen Aquaventure Fishery Inc, discussed challenges in the Philippines tilapia hatchery segment.
- **Jessica Kaye Turner**, Assistant Managing Director, Nam Sai Farms, Thailand, gave a SWOT analysis of the Thai tilapia industry; and
- **Arnan Hirunratanakorn**, Farm Manager, presented on predictive analysis for tilapia farming at Arnan Farm, Thailand.



A panel discussion on "Southeast Asia - Common Themes & Collaboration in the Tilapia Sector" was moderated by Benedict Tan, Programme Director, Hatch Blue, Singapore (left). From the right, Jessica Kaye Turner, Nam Sai Farms, Thailand; Hector S. Abes and Carlo Enrico A. Latonio, Kaizen Aquaventure Fishery, Philippines; Arnan Hirunratanakorn, Arnan Farm, Thailand; and Ronnie Tan, USGBC, Malaysia. Photo credit: USGBC.

Revival in the Philippines: Addressing the tilapia fingerling bottleneck

At the startup, Kaizen Aquaventures, Hector S. Abes and Carlo Enrico A. Latonio aim to address the short supply of fingerlings to revive the tilapia industry in the Philippines.

Beginning with the state of the industry and their role in improving its future, Hector said that the Philippine tilapia industry may have demonstrated remarkable resilience, but it continues to face significant structural challenges.

The Philippine tilapia industry consists of approximately 725 hatchery farms, around 75,851 grow-out farms, 48 feed millers and 15 dedicated fish food processors. These are heavily concentrated in a few regions. Production dropped during the pandemic (2020); however, after COVID-19, the government supported the industry through programs and increased production to almost 280,000 tonnes. Consequently, in 2022, several typhoons and flooding caused a dramatic reduction in production and rising costs due to the Russia-Ukraine conflict, leading to the slow growth of the industry in 2023–2024. Production in 2024 was around 260,000 tonnes.



Hapas for tilapia nursing at Kaizen Aquaventures, Philippines. Photo credit: Kaizen Aquaventures

Heavily concentrated in Central Luzon

Approximately 66% to 70% of the national tilapia production comes from central Luzon, where many hatcheries are also located. While this concentration creates efficiencies in logistics, transportation and supply chain management, it also creates significant risks. When climate events, disease outbreaks or supply disruptions occur in these key production areas, the effects are felt throughout the entire national tilapia supply chain.

According to the Philippines Statistics Authority (PSA), based on per capita fish consumption, the country will require approximately 325,000 tonnes of tilapia by 2025, which will need an estimated 2.7 billion tilapia fingerlings. Hector argues the gap between fingerling supply and industry demand is enormous, as the country currently produces only around 300 million tilapia fingerlings annually.

"Conversations with farmers across the country reveal that farmers repeatedly face inconsistent fingerling quality, uneven growth rates, high mortality and longer culture cycles." He added, "Tilapia farming can feel like a gamble—sometimes yielding strong returns, and at other times, causing them to miss production cycles."



"Conversations with farmers across the country reveal that farmers repeatedly face inconsistent fingerling quality, uneven growth rates, high mortality and longer culture cycles," says Hector S. Abes, CEO, Kaizen Aquaventures, Philippines.

Traditional practices and structural challenges

"The real bottleneck is not ponds but fingerlings," said Hector. Many hatcheries still rely on traditional methods, often lacking biosecurity measures, conditioning ponds and proper management practices. While other countries have moved towards modern systems such as hapa-based production and artificial incubation, the Philippine hatchery practices remain largely conventional. Some government-funded hatcheries have better infrastructure and facilities, but operations often cease when funding ends. In addition, fingerlings are frequently distributed free of charge, undermining nearby private hatcheries and distorting local markets.

Focus on underserved farmers

Kaizen Aquaventures focuses on serving underserved farmers who need reliable, high-quality fingerlings and ongoing technical support. Established in 2024, they currently operate a 3ha hatchery farm. They are accredited by the Bureau of Fisheries and Aquatic Resources (BFAR), allowing them to supply fingerlings to government programs. The company currently participates in projects in Regions I and III, is a member of the Philippine Tilapia Commodity Board, and collaborates with fisherfolk associations throughout the country. Kaizen actively seeks out smaller fisherfolk organisations in underserved provinces and supplies them with quality fingerlings to improve local tilapia production.

Fingerlings are delivered even to remote locations, including isolated communities accessible only through challenging transportation routes, sometimes crossing mountainous terrain using tramline systems. Some 10-15% of the production is supplied to poor farmers. Through access to quality fingerlings, technical training, and government assistance, many of these groups have regained confidence in fish farming.

Investing in the next generation

Kaizen Aquaventures is not only focused on business; it also recognises the urgent need to renew an ageing aquaculture workforce, with fish farmers averaging about 58 years old. To help secure the industry's future, the company actively recruits and trains young people for careers in aquaculture. As a bootstrapped startup, Kaizen lacks access to the costly commercial artificial incubation systems used by larger hatcheries. Instead, its team developed a low-cost artificial incubator after studying systems in Thailand and Brazil and reviewing available YouTube videos.

The company plans to expand its hatchery to 9ha within the next year. It is also forging partnerships with local universities and international organisations to advance research in genetics, water quality management and hatchery innovation.



Clockwise from top left: Established in 2024, Kaizen Aquaventures currently operates a 3ha hatchery farm. It will expand to 9ha in 2026; Working with hapas for breeding; Hector S. Abes and delivery of juvenile tilapia crossing mountainous terrain using tramline systems; Innovative low-cost artificial incubator after studying systems in Thailand. Photo credit: Kaizen Aquaventures

Producing disease resistant monosex tilapia fry

Jessica Kaye Turner believes there is significant potential for increasing tilapia production in Thailand. Nam Sai Farms addresses the challenges by taking an active role in the advanced hatchery, fry production and distribution network.

Thailand remains one of the world's leading tilapia producers, although competition within Asia is intensifying. Thailand ranked sixth with 266,000 tonnes, but was overtaken by Vietnam in 2024, which produced 316,000 tonnes. Despite this increasingly competitive landscape, Thailand's tilapia industry continues to benefit from its strengths: decades of technical expertise, a favourable tropical climate that supports year-round production, strong domestic demand, and an advanced hatchery and fry distribution network driven largely by private sector investment.

However, only about 2.6% of national production is exported, reflecting both strong local consumption and challenges in meeting export market requirements. Production continues to increase, although the rate of growth is slow, while farmgate prices have stayed relatively stable at approximately USD 1.5/kg for Nile tilapia and USD 2.6/kg for 1.0–1.5 kg red tilapia.



"Thai farmers are very adept in farming, but many farmers lack expertise in marketing and product development," says Jessica Kaye Turner, Nam Sai Farms.

Off flavour hinders exports

In terms of weaknesses, Jessica noted that since tilapia production in Thailand is dominated by earthen pond farming, a major hurdle is off-flavour or muddy taste. This is caused by compounds such as geosmin and 2 methylisoborneol (MIB), both produced by specific microorganisms in freshwater green water systems. This remains a major obstacle to export its tilapia. High feed costs continue to constrain profitability, particularly for cage culture operators who rely almost entirely on commercial feeds. Disease outbreaks, water pollution and flash floods pose additional risks, especially in open water cage systems where biosecurity and water quality control are difficult to maintain. Jessica views tilapia feed prices, which are nearly 30% higher than those in Vietnam, as a disadvantage for the industry.

"Farmers are very adept in farming, but many farmers lack expertise in marketing and product development. They face pricing pressure from middlemen, who often capture a disproportionate share of the value chain, leaving producers with thin margins and limited bargaining power," said Jessica.

There are opportunities for Thailand. It already has a global position as a supplier of tilapia seed. Although annual exports of tilapia products total only around 7,000 tonnes, Thailand exports significant volumes of fry to markets including Vietnam, Malaysia, Saudi Arabia, Ghana and Jordan. The annual export volume is estimated to exceed 100 million fry from hatcheries in Thailand. Jessica says another opportunity lies in farming tilapia in fertilised green brackish waters, which can eliminate off-flavour and potentially open access to export markets.

Survival over rapid growth

Nam Sai Farms established 32 years ago, specialises in male monosex and red tilapia fry production. While growth rate and body shape are important traits, the hatchery prioritises disease resistance above all else. Fast growing fish are of little value if survival rates are poor. "The goal is to produce fry capable of thriving under real farming conditions," noted Jessica.

Exposing fish to natural challenges

Rather than raising broodstock in highly controlled environments, the hatchery uses earthen ponds that closely resemble the conditions experienced by farmers. Fish are exposed to natural challenges, including changing weather, phytoplankton rich water and naturally occurring pathogens. Jessica argues that with this approach, they do not push for biosecurity but encourages natural selection, allowing the strongest fish to survive and pass their traits to future generations.

Broodstock are ready for egg collection at around six months of age and weigh 80–100g. Eggs are collected every six days, with each female producing between 500 and 2,000 eggs per spawning cycle. After collection, eggs are sorted by developmental stage, which are 24 hours apart and disinfected with potassium permanganate and incubated in systems designed to mimic maternal mouthbrooding.

Once the fry reach the swim up stage, they are transferred to a sex reversal nursery for approximately 21 days, or up to 25 days during cooler months. Fry are fed intensively and graded by size before sale at 0.25g. Any undersized fish remain in the nursery for an additional week before being graded by size again.

Quality control is rigorous. Samples from every batch are reared to 5–10g and examined microscopically to verify that male populations exceed 99%. Automation further improves efficiency, with modern counting and packing systems capable of processing up to 300 bags of fry per hour while reducing handling stress and human error.



Photo Credit: Nam Sai Farms

Turning past "patterns" into future predictions

Arnan Hirunratanakorn believes that a data driven farm management approach based on predictive analysis is the right path to profitability

Most problems don't just happen. They usually leave signs before they occur." For Arnan Hirunratanakorn, Farm Manager at Arnan Farm in Thailand, predictive analysis means examining historical and current data to identify patterns that indicate future outcomes. The approach is simple: collect data, identify patterns, and use them to make better decisions before problems arise. "Like the weather forecasts, this is still not perfect, but it is better than just guessing," said Arnan. All over Southeast Asia, common issues revolve around, from biological - biomass in the pond and mass mortality to physical, such as uncontrollable water quality and electricity breakdowns.



"When the estimates were measured against the actual results, there was only an error rate of approximately 5%, making the formula a useful management and planning tool," says Arnan Hirunratanakorn.

A farm built on data

Established in 1991, Arnan's family farm has accumulated more than three decades of production records. The 50ha polyculture operation holds multiple certifications and serves as a learning centre for aquaculture management and production. Despite this, the farm remains largely traditional rather than high tech.

The farm records production data including stocking, growth, size sampling, mortality, harvests and size distribution. It also tracks feed inputs, lime, fertilisers and minerals. Water quality records include pH, alkalinity, ammonia, dissolved oxygen, and day and night temperatures. Unusual events such as weather changes, disease outbreaks and mortality incidents are also documented, often providing valuable clues when analysing patterns.

Data collection is traditional but consistent

Most records are still collected on paper. Daily logs include feed usage, water applications, fertiliser inputs, harvests and production activities. At the end of each year, the data is digitised, allowing the farm to identify trends, develop formulas and build predictive models.

Predicting pond biomass

Estimating tilapia biomass is a common challenge. Arnan shared how his methods allowed him to predict biomass for every kg of feed. Historical records showed a relationship between the final daily feed input before fasting and eventual harvest weight. Fish are starved before harvesting.

Pond number	A. Last daily feed input (kg)	B. Total harvest (kg)	Estimate biomass (kg) per kg feed (B/A)
A01	320	25, 768	80.52
A02	120	9,750	81.25
A04	320	25,298	79.06
A05	240	18,363	76.51
A07	100	8,226	82.26
Average			79.92 *

*Rounded at 80kg tilapia produced for one kg of feed

Estimate Biomass =Last Daily Feed x 80

Table 1. An example of the calculations of data from 5 ponds in 2025. After analysing multiple ponds and production cycles, the farm identified an average multiplier of 79.92, rounded to 80.



Most records are still collected on paper. At the end of each year, the data is digitised, allowing the farm to identify trends, develop formulas and build predictive models.



Graphs are created to share data trends with workers, so they can better understand pond conditions, see the bigger picture and recognise the value of careful data collection.

Identifying a hidden mortality problem

Arnan explained that one pond consistently experienced daily loss leading to an annual mortality ranging from 3,000 to 12,000 fish, while other ponds under the same management did not. Investigations revealed highly acidic soil, low mineral content, low pH, low alkalinity and poor water quality. These conditions were unsuitable for both tilapia and phytoplankton production. Regular fertiliser applications were introduced to raise pH, increase alkalinity and stabilise water quality. The recurring mortality pattern disappeared and has not returned. Arnan added, "I would not know if we have not been consistently recording data."

Predicting crop profitability

A typical crop lasts around eight months. "Yet, my father can often predict profitability after only two months by recognising patterns repeatedly observed in previous production cycles. As more data accumulates, predictive models become increasingly sophisticated."

Applications include forecasting stocking needs, oxygen trends, aeration requirements and production levels. Long-term dissolved oxygen records help determine when aerators should be activated, reducing energy costs while improving efficiency and growing conditions. The farm also uses external data from the government's website giving information on the river conditions, since it depends on this water resource; for example, forecasts for January and February help the farm prepare for the rainy season.



The limits of predictive analysis

Predictive analysis supports decision making but does not replace human judgment. No single model works for every farm, as species, feeds, management practices, climate and water conditions differ.

"Today, we talk about AI and smart farms, and several predictive models are available for farmers to input. The accuracy of predictions ultimately depends on data quality. The more consistently and accurately data is collected, the more reliable the results become."



Tilapia farming in Thailand: Production shifts and generational change

Somsak Hirunratanakorn and son, Arnan, use extensive pond data to guide tilapia production at their farm in Chachoengsao province, changing harvest sizes to consumer demand

By Niran Warin and Zuridah Merican



A grow-out pond at Arnan Farm in Chachoengsao province.

This Thai tilapia farming story spans 30 years, tracing the shift from traditional practices to semi-intensive and modern biosecure production, while moving into its third generation. Arnan Farm, located in Phanom Sarakham district, Chachoengsao province, is recognised as a model farm and serves as a Department of Fisheries learning centre for tilapia farming. The farm produces 300 tonnes of tilapia annually, with productivity of one tonne per rai of pond area; one rai equals 1,600m^2.

Khun Somsak's success was built through trial and error. Over the years, he has diligently recorded farm data and used it to understand problems and events while continually refining farming practices. At a meeting in Cebu, Philippines, for next-generation shrimp and tilapia farmers, Arnan described the extensive data collected over 30 years and explained how he is now digitising it to develop predictive analysis (see page 48).

Moving to large fish

Established in 1991, Arnan Farm has a land area of 50 ha, with ponds of 10-50 rai in size, stocked with tilapia and white shrimp. Ponds are divided by function: one large reservoir pond for water treatment, four 4 rai nursery ponds and eight grow-out ponds. This is a long way from the early days, when Khun Somsak's father first began farming tilapia. It started as a backyard activity at a chicken farm in Bangkok, where waste from the poultry farm fertilised green-water ponds for the fish.

In the beginning, when the business was small, the farm operated on an all-in, all-out system, harvesting fish at 300g. "Back then, I was producing good-quality fish with a consistent supply, so I could tell the middleman my price. Nowadays, it is the reverse. The middleman sets the price based on size. Gradually, I migrated to producing larger fish, harvesting 600-700g, then 800g and subsequently 1kg. We stood out as we could produce these sizes, but today the market is saturated, as most farmers can easily produce 1 kg fish," said Khun Somsak.

From monosex tilapia to off-flavour control

The farm is recognised as the first in the province to farm monosex tilapia. About 30 years ago, the farm began using male monosex fry from Nam Sai soon after owner Warren Turner started production. Khun Somsak observed improved growth performance and has remained a loyal Nam Sai customer ever since.

He is also known for producing tilapia without off-flavour or muddy taste, making his fish highly sought after. Arnan recalled a recent visit when he, representing the farm's third generation, and Jessica, Nam Sai's second generation, reviewed off-flavour in a harvest. The farm had been testing brackish-water culture as a way to prevent off-flavour, and the results were encouraging.

Father and son attribute these qualities to three practices: using 25% crude protein (CP) pelleted feed without relying on natural food, maintaining water quality and avoiding intensive farming. Ponds are cleaned for two weeks after each crop. "Our emphasis is on minimising the impact of overfeeding on water quality. We monitor feed consumption and reduce uneaten feed. Part of our SOP is the regular use of probiotics to manage soil condition."

A few years ago, as part of his effort to eliminate off-flavour, Khun Somsak raised tilapia in 8-20ppt saline water and then reducing water salinity to zero. The approach worked—the fish had no off-flavour—but growth was slow, taking one year to reach 600g. By comparison, pellet-fed fish in freshwater ponds reached 600g in five months. For the farm, shortening the farming cycle is essential to meet market demand.

Caution with pre-stocking tests

The farm stocks each 4-rai nursery pond with 100,000 fry of 0.2g, (25,000 fry/rai). The nursery phase lasts two months but may be extended if the grow-out ponds are not ready. Juveniles, usually weighing 20–30g, are then transferred to grow-out ponds, where stocking density is typically 1,000–1,200 fish/rai. Arnan explained, "If nursery-stage mortality is high, we reduce grow-out density to 800–900 fish/rai. We may also keep fish longer in the nursery and transfer larger juveniles of about 35g."

The farm produces fish weighing 700g to 1.4kg, with an average size of 1kg. Each crop takes eight months, allowing 1.5 cycles per year. "If the market is unfavourable, we delay harvesting. Under current economic conditions, some fish have remained in the ponds for nine months," said Arnan, adding that consumers are shifting towards barbeques with pork and eating less fish.

As part of the farm's SOP, 1,000 fish are first stocked in a small cage in a nursery pond and monitored for five to seven days. The same procedure is used in grow-out ponds, where 1,000 fish are held in a larger cage. "This allows us to identify the cause of any mortality. High mortality in the nursery may indicate transportation stress, while high mortality in grow-out may point to pond water-quality problems. It is a better approach than releasing fry or juveniles directly into a large volume of water, where dead or moribund fish may not be seen, and the cause cannot be traced."

Planning harvests, linking prices

Arnan linked tilapia prices to farming conditions, weather and demand. In March, low water levels force many farmers to harvest, pushing prices down. April is typically a recovery month, while disease outbreaks and flooding in early May further weaken prices. After a period of low prices, the market rebounds; by late May, prices rise and usually stay high through year-end. He added that festivals have little influence on prices.

"Although Streptococcus outbreaks affect all farms, their impact is less severe at our farm. Our response is to remove affected fish, reduce feeding and change the water quickly. Our large reservoir pond gives us an advantage."

In Thailand, tilapia prices are linked to size: the price/kg falls as fish size increases, with fish above 1.4kg receiving the lowest prices. In March 2026, prices opened at THB45/kg for mid-sized fish, THB30/kg for larger fish, and THB25/kg for jumbo fish.



The Arnan Farm, operated by Somsak Hirunratanakorn and son, Arnan is recognised as a model farm and serves as a Department of Fisheries learning centre for tilapia farming.

"Today, a 1.4kg fish fetches the same price as a 600g fish," Arnan said. "Customers still prefer whole fish, but we need to shift their focus to fillets. That would support farming larger fish of about 1.5kg. However, we still have a long way to go."

Long-term pond records

Over 30 years, Khun Somsak has collected extensive farm and pond data, storing the records both digitally and in hard copy. His weather records show May as the hottest month, with morning water temperatures around 23°C and afternoon temperatures reaching 29°C. Oxygen levels were measured twice daily throughout each cycle. They were generally higher in the evening than in the morning, and higher early in the cycle when fish were smaller, before declining as the fish grew. This pattern is linked to increased phytoplankton levels associated with feeding practices.

Turning records into practical learning

Khun Somsak shares data trends with workers so they can better understand pond conditions, see the bigger picture and recognise the value of careful data collection. "We want the workers to understand and stay motivated. Although the cost of collecting oxygen and pH data is high, being able to create graphs makes the expense worthwhile."

Using feed data to guide decisions

Feed is the farm's largest production input, accounting for 70% of total costs. The farm uses grow-out feed from a single supplier. Over the past two years, feed prices have risen following the Ukraine war and have remained high. Khun Somsak has analysed the average daily growth (ADG) of three grades of feed by the same feed mill; premium feed at 7g/day; medium-grade feed at 6g/day and standard feed at 5–6g/day. His feed selection varies according to farming conditions and market demand.



From the right, co-author, Niran Warin is a committee member at the Thai Aquaculture Business Association (TABA), Zuridah Merican, Somsak and Arnan Hirunratanakorn and Ronnie Tan, USGBC, Malaysia.

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Leveraging programmable nanopeptides against Streptococcosis in tilapia

A paradigm shift in fish health management with oral delivery of immune protection

By Rishita Changede, Ponsrinivasan A, Abhijith E K and Dhaval C Bamaniya



Tilapia harvesting and sorting at pond-side, supporting rural livelihoods. Photo credit: Nooknick Putsorn, Future Fish, Thailand.

Nile tilapia (*Oreochromis niloticus*) is among the most widely farmed finfish species worldwide, with an annual production exceeding 5 million tonnes and an estimated market value of approximately USD 11 billion (FAO, 2025). Although tilapia aquaculture continues to expand globally, disease management remains a major bottleneck to sustainable production.

Among bacterial pathogens, *Streptococcus agalactiae* has emerged as a major threat, driving recurrent outbreaks, high mortality rates, and substantial economic losses in intensive aquaculture systems. Despite decades of research and the availability of effective injectable vaccines, global vaccination coverage remains strikingly low. Industry estimates indicate that less than 5% of farmed tilapia are vaccinated globally, with adoption highly uneven, ~35% in Latin America versus below 1% in Asia and Africa (Howell, 2021). More recent data suggest only modest improvement, with ~1% vaccination in Asia compared to ~35% in Brazil (Cascione, 2024; TARS 2024) and ~2–3% global coverage overall (Komar, 2025; INFOFISH Tilapia, 2025).

Importantly, the limited uptake reflects the economic and structural realities of tilapia farming rather than the effectiveness of existing vaccines. Tilapia is a low margin farmed fish, often produced in decentralised systems where economies of scale are limited and low upfront costs are essential. Consequently, even effective vaccination programmes are difficult to implement commercially, leading many producers to rely on reactive disease management, including antibiotics. Consequently, there are growing concerns about antimicrobial resistance (AMR) as well as environmental sustainability and animal welfare (Cabello, 2006; Rico et al., 2013). Accordingly, there is growing interest in complementary approaches that maintain protection while improving scalability, cost-efficiency and welfare outcomes.

The rising global threat of Streptococcosis in tilapia aquaculture

Despite tilapia's commercial success, acute outbreaks continue to limit productivity, particularly bacterial infections caused by *S. agalactiae*, the etiological agent of streptococcosis. The pathogen causes acute systemic infections that result in high mortality and substantial economic losses, making streptococcosis one of the most economically damaging bacterial diseases affecting tilapia aquaculture, especially in intensive culture systems.

Outbreaks of streptococcosis have been reported across major producing regions, including China, Egypt, Indonesia, Thailand, Brazil and Latin America. Mortality rates during outbreaks commonly range from 40–80% and may exceed 90% under severe farming conditions (Amal & Zamri-Saad, 2011; Dong et al., 2017). Recent estimates suggest that annual economic losses linked to streptococcal infections in tilapia farming ranged between USD 150–250 million globally, with substantial production losses reported across Asia and Latin America (Liu et al., 2024).

S. agalactiae is a Group B Streptococcus (GBS). It includes multiple capsular serotypes, of which Ia, Ib, II, and III are most frequently associated with tilapia infections. The bacterium demonstrates high virulence and strong tropism for the central nervous system,

commonly resulting in meningoencephalitis. Recent epidemiological studies from major aquaculture-producing countries continue to report widespread outbreaks, increasing antimicrobial resistance and significant serotype diversity, further complicating disease control strategies (Kayansamruaj et al., 2020; Lusiastuti et al., 2021). The increasing global prevalence, high mortality and growing economic burden of streptococcosis highlight the urgent need for preventive approaches that combine biological efficacy with practical applicability in large-scale aquaculture operations.

Smart immunity – simplified

Today, nanopeptides are emerging as a promising approach for mimicking natural pathogen entry pathways and activating the host's immune system. Teora's patented SOALQ platform provides a molecular carrier that facilitates direct delivery to the mucosal immune system. As a coated oral feed, they can be applied at any life stage, enabling immune priming before periods of disease risk. This approach may reduce reliance on antibiotics and support stronger, biologically primed immunity in tilapia.

Teora's encapsulated nanopeptides interact with key immune receptors, such as Toll-like receptors (TLRs), and trigger downstream immune signalling. This activates innate immune responses, including cytokines, while also enhancing antigen presentation through MHC pathways. With intrinsic adjuvant-like properties, this supports immune priming and coordination between innate and adaptive immunity. Importantly, these nanopeptides are produced using naturally derived microbial expression systems in controlled fermenter environments, ensuring consistency, scalability and cost-effective manufacturing suited for large-scale aquaculture applications. In this article, we highlight the efficacy of our nanopeptides solution, specifically designed to combat *S. agalactiae* in tilapia.

Protective efficacy under laboratory challenge conditions

The efficacy of the orally delivered FishGuard Nano-Sa was evaluated against serotypes Ia and Ib of *S. agalactiae* under controlled laboratory challenge conditions. The nanopeptides solution was incorporated into commercial pellet feed using a standardised coating protocol. The formulation is mixed with a suitable binder, evenly coated onto feed pellets at an inclusion level of approximately 2% and air-dried for storage (Figure 1).

Healthy Nile tilapia (*O. niloticus*) with an average body weight of 0.5 ± 0.05g were randomly allocated to treatment and control groups. Each group consisted of 90 fish maintained in three replicates to ensure the reliability and reproducibility of the results.

Immunisation and pathogen challenge

Fish in the treatment group received the experimental feed according to a two-dose immunisation schedule prior to pathogen challenge, with the dosage determined based on previous immune response studies. Fish in the control groups were given uncoated basal feed. The detailed trial design and immunisation schedule are presented in Figure 2A.

For each serotype challenge study, 24 fish were assigned to each treatment and control group and distributed equally across three independent replicate tanks. Fish were challenged by intraperitoneal injection with *S. agalactiae* Ia and Ib individually at a standardised LD_{50} dose of $1.5x10^4$ CFU/mL in a final volume of 100 µL per fish. Mortality was recorded daily for 30 days post challenge. The challenge experiment was considered valid when cumulative mortality in the control group reached approximately 50%.

To evaluate the duration of immunity, fish from the same treatment groups that had not been previously challenged were maintained under identical rearing conditions and subjected to a secondary challenge at 74 days, following the 21-day secondary-dose treatment. Fish were challenged via intraperitoneal injection with a combined inoculum of *S. agalactiae* serotypes Ia and Ib (Strain ID 1a: ARL/BAC/ON/SAG/ST1/2024/026; 1b: ARL/BAC/ES/SAG/ST2/2024/048) administered at the LD_{50} dose. The challenge experiment was monitored until the cumulative mortality of the control group reached approximately 50%.

Assessment of protective efficacy

Humoral immune responses were assessed by measuring serum IgM levels in treated and control group fish at defined time points - D0, D10, D18 & D28. IgM levels were determined using ELISA. Protective efficacy was evaluated using cumulative mortality and Relative Percent Survival (RPS). Survival data were analysed using Kaplan–Meier survival curves, and statistical differences between groups were evaluated using the log-rank test. IgM data were analysed using one-way analysis of variance (ANOVA). Statistical analyses were performed using GraphPad Prism, and differences were considered significant at $p < 0.05$.



Figure 1. Preparation of tilapia feed with FishGuard (Nano-Sa).

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Table 1. Growth performance and feed utilisation of fish in treatment groups before challenge.

Treatment	Initial weight (g)	Final weight (g)	Weight gain (g)	SGR (%/day)	Feed intake (g)	FCR
FishGuard (NanoSa)	0.5	5.7	5.2	5.94	2.54	0.49
Control	0.52	3	2.48	4.27	1.44	0.58
FCR = feed conversion ratio; SGR = specific growth rate						

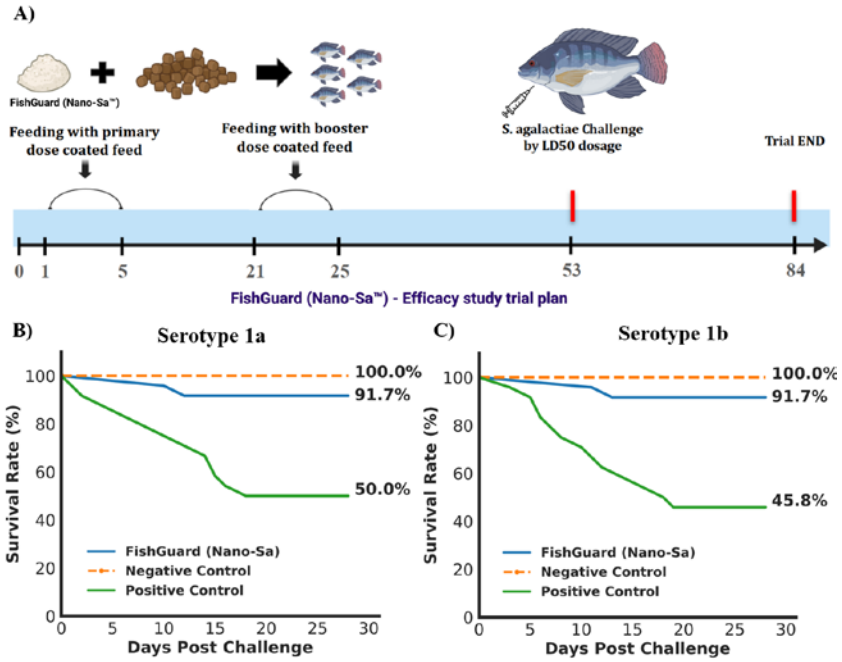


Figure 2. Experimental design and result of efficacy assessment of FishGuard (Nano-Sa) oral nanopeptide following pathogen challenge with *Streptococcus agalactiae* serotypes Ia and Ib. A) Experimental plan for the efficacy study, B) Percentage survival of tilapia 30 days after infection with *S. agalactiae* serotype Ia via intraperitoneal injection at the LD_{50} dose. C) Percentage survival of tilapia 30 days after infection with *S. agalactiae* serotype 1b via intraperitoneal injection at the LD_{50} dose. Treatment groups showed significantly improved survival compared to the positive control ($p < 0.05$, log-rank test after Kaplan-Meier analysis).

Growth performance

The treated groups showed improved growth performance and feed utilisation without noticeable adverse effects or treatment-associated mortality during the pre-challenge period, indicating good safety and physiological compatibility under the tested conditions. The growth performance data are presented in Table 1.

Efficacy study

After performing safety studies where the weight, growth and survival of the fish were found to be comparable to the control groups, extensive efficacy studies were performed where the treated and untreated fish were challenged with the pathogen. FishGuard (Nano-Sa) achieved strong protective efficacy across both serotypes, where treated fish exhibited markedly reduced mortality, with survival as high as 91.7%, compared to significantly higher mortality in control groups. This corresponded to RPS values of greater than 83% for serotypes Ia and Ib at 30 days post-challenge, indicating consistent cross-protection (Figure 2B & 2C).

In addition to improved survival outcomes, immunological evaluation showed a significant enhancement in humoral immune responses following the administration of the nanopeptides solution. Fish in the treated group exhibited markedly elevated serum IgM levels from Day 10 onward compared to both negative and positive control groups, with peak IgM responses observed at Day 18 (0.65 ± 0.07). In contrast, IgM levels in the control groups remained comparatively low throughout the experimental period. These findings indicate that FishGuard (Nano-Sa) effectively stimulated a sustained humoral immune response, supporting its immunogenic potential (Figure 3). IgM data were analysed using one-way ANOVA, with statistical significance considered at $p < 0.05$.

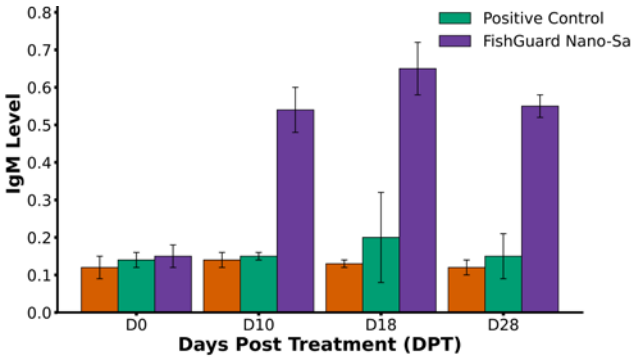


Figure 3. Humoral immune response following oral administration of FishGuard (Nano-Sa). Serum IgM levels (Ia) in FishGuard (Nano-Sa) treated and control fish at defined time points post-immunisation. ($p < 0.05$ at D10, D18 and D28).

Duration of immunity

Next, to assess the duration of protective immunity, fish fed with FishGuard (Nano-Sa) were maintained for an extended period and subsequently subjected to a *S. agalactiae* challenge under controlled conditions. At 99 days post-treatment, 12 fish per treatment were challenged via intraperitoneal injection using a combination of *S. agalactiae* serotypes Ia and Ib as shown in Figure 4A. The two serotypes were cultured independently, quantified and combined to prepare the final challenge inoculum. Fish were administered a total dose of 1.5×10^4 CFU/mL per fish, equivalent to the LD_{50} dose used in the primary challenge, thereby ensuring consistent infection pressure across challenge studies. Mortality was monitored daily, and the experiment was continued up to 10 days post-challenge, at which point control group mortality reached approximately 50%.

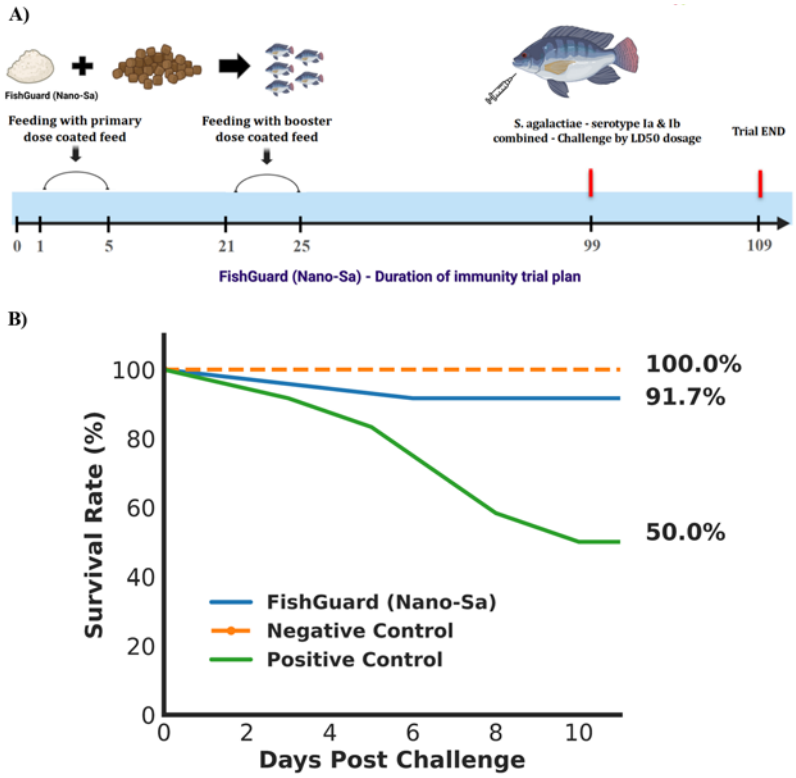


Figure 4. Experimental trial plan and the result of duration of immunity study of FishGuard (Nano-Sa) oral nanopeptide following challenge with *Streptococcus agalactiae* serotypes Ia and Ib, 3 months after immune stimulation. A) Experimental trial plan for duration of immunity study; B) Percentage survival of tilapia 10 days after infection with *S. agalactiae* (1a and 1b) via intraperitoneal injection at LD_{50} dose.

Following the secondary exposure, treated fish exhibited survival rates exceeding 90%, with Relative Percent Survival (RPS) values remaining above 83%, whereas the control group showed 50% survival with substantially higher mortality, as shown in Figure 4B.

These results indicate the persistence of protective immunity for at least 110 days from the first treatment. The sustained protection observed following delayed heterologous challenge suggests the induction of a durable and cross-protective immune response against different serotypes of *S. agalactiae*. Furthermore, consistency of survival outcomes across independent validation trials supports the reproducibility and robustness of the observed protective effects.

A solution for protection against *S. agalactiae*

In this study, we showed a strong protection against *S. agalactiae* infection in fish, as indicated by reduced mortality and high RPS after challenge. Protective efficacy was observed against both serotypes Ia and Ib, suggesting that the nanopeptide formulation can induce cross-protective immunity. Oral administration via coated feed also elicited a measurable humoral immune response, reflected by increased IgM levels, indicating the activation of adaptive immunity and likely contributing to the observed protection.

Lastly, protection persisted after the secondary challenge at 99 days post-treatment, supporting the development of long-term immunity. The ability to maintain high survival rates under these conditions suggests that the nanopeptides may support long-term disease control in tilapia farming. Overall, the findings support FishGuard (Nano-Sa) as a scalable, non-invasive oral immunoprophylactic strategy for controlling streptococcosis in aquaculture, with advantages in ease of administration, reduced handling stress, operational flexibility, and potential reduction in the use of antibiotics.

References are available on request



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Dr Ponsrinivasan A is Scientist - Fish Pathology.



Abhijith E K is Senior Scientist – Bioinformatics.



Dhaval C Bamaniya is Business Development Manager

All authors are with Teora Pte Ltd, Singapore.

Improving practices in finfish hatcheries in Asia Pacific

INVE Aquaculture, a specialist in nutrition and health solutions for early fish/shrimp life stages, aims to improve finfish hatchery practices across Asia Pacific and China. During World Aquaculture 2026 in Singapore, the APAC team hosted an interactive workshop on current challenges in marine fish hatchery production. Teams from Thailand, Singapore and Europe presented practical solutions across the fish production cycle. Participants included farmers and hatchery operators working with barramundi from Australia, tilapia from Indonesia and the Philippines.

The presentations covered key stages in the finfish life cycle, including broodstock feeding, egg quality assessment, rotifer and *Artemia* control, specialised early-life feeds to improve robustness, survival and weaning performance, and probiotic solutions to reduce mortality and improve gut health.

Broodstock, live feed enrichment and larval diets

Valentina Carbone, Global Technical Expert Fish, introduced Fish™ Breed-M, a customisable powder mix for preparing moist feed with up to 35–40% moisture. Hatcheries can adjust feed size and form for different species and add specific ingredients when required. It is suitable for both marine and freshwater fish.

Carbone also introduced S.presso, a liquid enrichment for *Artemia* and rotifers, followed by Natura™ pRo, a highly palatable larval diet that can replace over 50% of rotifers and support dry feeding from mouth opening. Available in <100 µm (50–100 µm) and 100–250 µm sizes, Natura™ pRo helps reduce live feed use. Dr Young Chul Kim, R&D Trial Manager at INVE Aquaculture's Marine Aquaculture Centre in Singapore, discussed using Selco S.parkle, a ready-to-use dry diet for clean, high-density indoor rotifer culture.

Sea-cage health and probiotics

Sea transfer stresses fish by exposing them to new environments and pathogens. Thomas Raynaud, Product & Business Development Manager Diets, and Professor Andy Shinn, Global Technical Expert (Health), explained that probiotics can be given shortly before, during and after transfer. The probiotic strategy uses Sanolife®Pro FMC, added at the feed mill. In a Vietnam Asian seabass trial, probiotic feed conditioned fish onshore over 20 days by reducing gut *Vibrio*. In the control fish, *Vibrio* represented 44% of the gut community, while in the probiotic-fed fish it was only 9%. On day 35 at sea, probiotic-fed fish had 54 times lower *Vibrio* levels in the gut compared with the control group. Fin erosion was reduced from 32% in the control group to 21% in the probiotic-fed group.

Automation and digital tools for hatcheries

At Aquaculture Europe 2023, INVE launched SnappArt, a fully automated live-food counting system that replaces manual counting and helps hatcheries achieve more efficient, sustainable and consistent live-food production. It has since been upgraded.

Dr Geert Rombaut, Product Manager Artemia and Live Feed, demonstrated SnappArt 360 E-sense, which automates monitoring with accurate counts, embryonic-stage assessment and high-resolution imaging. Current species-specific modules cover gilthead bream, European seabass, Asian seabass, sole and turbot. Hatcheries can measure egg fertilisation and hatching rates, assess larval development and broodstock performance, and quantify fish larvae.

Launch of next-generation probiotic wafer

At the tradeshow, INVE launched Sanolife™ PRO-TAB, a next-generation probiotic wafer that supports fish health, resilience and survival during the critical nursery and pre-growing stages. Probiotics can significantly reduce mortality, especially when mixed with feed, but application is often limited by inconsistent intake, leaching and labour-intensive preparation. Sanolife™ PRO-TAB addresses these challenges with a delivery technology that ensures reliable intake and simplifies daily farm operations. www.inveaquaculture.com



The INVE Aquaculture team, partners and customers at the workshop included: From left, Dr Young Chul Kim (Singapore), Dr Sih Yang Sim (Malaysia), Matt Reason (The Company One, Australia), Harn Sheng Khor (Humpty Doo Barramundi, Australia), Valentina Carbone (Italy), Jason Clark (Humpty Doo Barramundi, Australia), Thomas Raynaud (France), Amir Khalil (Thailand), Justin Holgate (Australia), Benjamin Yeo (Malaysia) and Okdivina Sitepu (Regal Springs, Indonesia).

aquaculture europe 26

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Since 1976, EAS has been bringing people together for the sustainable development of European aquaculture. As we celebrate our 50th birthday, we look back on key moments and key persons that made EAS what it is today. And we also look forward - continuing to expand our student activities and network and propose benefits for members that are suited to their profile and needs. We will celebrate this milestone throughout the year on social media, and in person at Aquaculture Europe 2026 in Ljubljana, where we invite EAS members to join the celebrations.

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Innovation, food security and responsible aquaculture development

World Aquaculture 2026 Singapore (WA2026), organised by the World Aquaculture Society (WAS) and the Asian Pacific Chapter (WAS-APC), hosted by Singapore Food Agency (SFA), successfully concluded with the call for innovation, food security and responsible aquaculture development.

The event reaffirmed Singapore's position as a leading global hub for innovation, technology and sustainable aquaculture development (see pages 4-5). It welcomed over 2,000 participants from all over the world. The international trade show featured over 100 booths, showcasing the latest technologies, products, equipment, and services driving the advancement of global aquaculture.

The scientific and technical program was comprehensive, featuring 550 submitted abstracts, including 381 oral presentations, 169 e-poster presentations, and 40 technical sessions, reflecting the rapid progress in aquaculture science, innovation, and sustainable production practices.

US seafood market dynamics

The keynote speaker was Richard Barry, Director of Programs at the National Fisheries Institute, USA, who presented on the U.S. seafood market dynamics, focusing on sourcing trends and consumer behaviour in a changing trade environment. Seafood is the most widely traded animal protein, so U.S. supply, pricing, and consumption are closely tied to international production, trade flows, and policy changes.

Americans consume about 8.6kg of seafood/capita, far below consumption of chicken, beef, and pork. Shrimp and salmon lead US seafood consumption. Because domestic aquaculture and fisheries cannot meet total demand, the U.S. relies heavily on imports, which supply roughly 80% to 90% of seafood consumed in the country.

Barry described the global sourcing and supply chain and added in its vulnerability to disruptions and shocks. Tariffs has been and continues to be the most significant disruption.

Tariffs raise costs first for importers, who either absorb the cost through lower margins or pass it on to customers. Eventually, higher prices reach consumers, reducing demand. Since seafood demand is highly price-sensitive, suppliers may stock less product or shift away from the U.S. market toward destinations with fewer trade barriers.

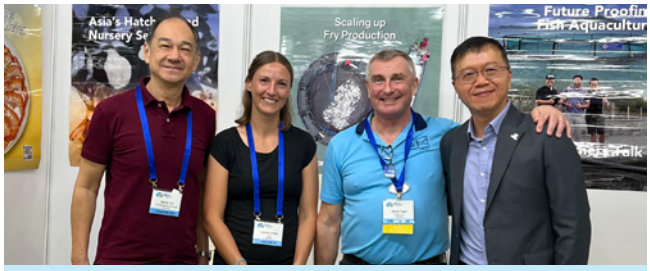
Shrimp illustrates how tariffs reshape trade flows. India has been the largest shrimp supplier to the US for the past decade, but a 50% tariff caused exports to fall sharply. Indian exporters responded by seeking alternative markets in China and the European Union (EU). After relying heavily on China before 2020, Ecuador diversified toward the US market when China became a more difficult trade partner. Ecuador also positioned itself to fill part of the gap left by India. However, Ecuador has limited capacity for value-added products such as cooked and easy-peel shrimp, so the US will still rely on India, Indonesia, Vietnam and Thailand for those products. These shifts demonstrate that trade in seafood is fluid and



The NSB-NB5 Aquafarm Corp team, from the left, Neslly, Neil and Nolan Bretana, with Franeza Nimenc, Philippines and Pearl Kwan, Republic Polytechnic, Singapore. NSB-NB5 Aquafarm Corp is a prominent aquaculture facility located in Sto. Rosario, Ajuy, Iloilo. The farm operates under strict, science-based protocols for sustainable and high-density vannamei shrimp.



At the EcoSeafood Group/ShrimpVet (Vietnam) booth, Founder & CEO Loc Tran (right) introduced Long Nguyen as CTO (left). From second right are Yin Min Thant and Thanh Chau.



From left, Ronnie Tan, Regional Aquaculture Consultant, US Grains & BioProducts Council, Malaysia; Hannah Jensen, Industrial PhD Candidate at Unibio, Denmark; Dan Fegan, Technical Consultant at I&V Bio, Thailand and Fuci Guo, Singapore.



At the Arsal LLC, Russia booth, Emeritus Professor Simon Davies of Aquaculture Nutrition at Harper Adams University, UK with Olga Khimchenko (left) and Evgeniia Popova. Arsal markets dry activated Artemia cysts.

LACQUA

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"Aquaculture Driving Blue Transformation"

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Hosted By: The United Republic of Tanzania Ministry of Livestock and Fisheries; Ministry of Blue Economy and Fisheries (Zanzibar)

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Aquaculture America 2027

Honolulu, Hawaii
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APA 2027

Asian-Pacific Aquaculture 2027

Blue Aquaculture for Resilient Future:
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7-10 September, 2027

Nha Trang, Vietnam

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For More Information:

Event Information: www.was.org
Conference & Registration: worldaqua@was.org
Tradeshow: mario@marevent.com



Vinothkumar R, Senior Global Communications Manager at Kemin AquaScience™ (second right) team.

can adapt to external shocks, though winners and losers change over time.

Barry added that two additional factors are being monitored closely. First, a major *El Niño* event is expected to affect the Peruvian anchoveta fishery, which is critical to fish feed. If fish feed costs rise by 8% to 10%, those costs could move through the aquaculture supply chain. The Strait of Hormuz blockade has created volatility in energy prices. Higher fuel and energy costs affect every stage of the seafood supply chain and ultimately contribute to higher consumer prices.

Consumers face food and energy inflation, weakening confidence and purchasing decisions. In grocery stores, seafood competes with lower-cost proteins such as chicken, while perceptions that it is expensive or hard to prepare limit home consumption.

Next in 2027

Asian Pacific Aquaculture 2027 (APA2027), which will continue to strengthen global cooperation, innovation, and sustainability in the aquaculture sector will be held from September 7-10, 2027, at Nha Trang University, Vietnam. www.was.org



Rudi Bijnens, Global Marketing & Sales Director (centre) and Dan Fegan, Technical Consultant (second left) with the **I&V Bio** team. I&V Bio has a strong operational presence across Thailand, India, Indonesia, Vietnam, Bangladesh, Ecuador and Saudi Arabia. It produces live *Artemia* nauplii daily in biosecure facilities and delivers fresh to support healthy shrimp larvae development at the early stages. In India, it offers a 1 Lakh Pack of enriched *Artemia* for feeding shrimp in grow-out ponds after stocking for the first 7 days and nurseries. www.iandv-bio.com

The **Aker QRILL Company** Aqua team was represented by, from left, Chaiyot Rawekchom, Regional Sales Director SEA (Thailand), Atul Barman, Managing Director India; Daranee Seguin, VP Shrimp Health & Nutrition (Thailand); Anagha Mehta, Marketing and Content Manager (India); Yen Nguyen, Country Manager, Vietnam. Back row, Sigve Nordrum, Head of Science & Marketing, Feed Ingredients Commercial, and Cici Chen, Marketing Manager.

Aker QRILL Company is a speciality company focusing on the sustainable harvesting of Antarctic krill (*Euphausia superba*), and on the development of krill-based ingredients for nutraceutical, aquaculture, and aquafeed applications. During the conference, Daranee presented on krill derived functional nutrition for EHP mitigation and improved osmoregulation and stress robustness in Pacific white shrimp. www.qrillaqua.com



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First BAP-certified producer in Belgium



Bern Aqua, an ADM group company and leading supplier of hatchery and nursery feeds for fish and shrimp, has become Belgium's first Best Aquaculture Practices (BAP)-certified producer with the certification of its Olen feed mill. The milestone underscores growing industry demand for greater traceability, responsible sourcing and third-party certified feed production across the global aquaculture value chain. The announcement reflects ADM's continued investment in aquaculture, where Bern Aqua plays a key role in delivering early life-stage nutrition solutions that support more sustainable seafood production.

Bern Aqua supplies feed for hatcheries and nursery farms in more than 50 countries, applying the latest advances in nutritional sciences into their manufacturing processes and products. With almost 25 years of experience in the aquaculture industry, they have become experts in advanced nutrition and environmental solutions for the first stages of life for fish and shrimp. Through innovative feed technologies, such as cold extrusion that preserves the nutritional value of ingredients, Bern Aqua delivers high-quality hatchery and nursery feeds that support animal performance. The company also prioritizes sourcing ingredients from certified, sustainably managed sources, enhancing supply chain traceability and supporting responsible aquaculture production. Bern Aqua produces aquafeed pellets ranging from 5µm to 3mm, tailored to the specific nutritional requirements of aquatic species.

"We are incredibly proud of this certification, which marks an important step forward in our mission to deliver superior nutrition solutions for the early stages of fish and shrimp life," said Plant Manager Sam Valgaeren. "This achievement, as with our organic certification and other accreditations, demonstrates how Bern Aqua is well-positioned to continue driving progress and enhancing our competitive edge in the field of early life nutrition."

"We congratulate ADM's Bern Aqua facility for becoming the first BAP-certified producer in Belgium, an important milestone for responsible aquaculture in the region," said Sébastien Metz, from the Market Development Team at the Global Seafood Alliance. "Feed plays a critical role in the aquaculture supply chain, and this achievement reflects their leadership in creating a more responsible future for global seafood production." www.bernaqua.com

2026

August 19-20
TARS 2026: Aquafeeds
Bali, Indonesia
tarsaquaculture.com

September 1-3
Global Shrimp Forum
Utrecht, The Netherlands
shrimp-forum.com

September 2-4
Seafood Expo Asia Singapore
seafoodexpo.com/asia/

September 8-10
Aqua Tech Taiwan 2026
Taipei
taiwanagriweek.com/en/about/aquatech

September 21-24
The Responsible Seafood Summit/ Shrimp Summit
Bangkok, Thailand
events.globalseafood.org/responsible-seafood-summit#navbar_global

September 24-26
Future Fish Eurasia
Izmir, Türkiye
eurasiafairs.com/eng

September 28-October 1
Aquaculture Europe 26
Ljubljana, Slovenia
aquaeas.org

October 21-22
12th International Conference of Aquaculture Indonesia (ICAI) 2026
Semarang
mai.or.id/icai-2026-2/

December 1-4
World Aquaculture 2026 Tanzania & AFRAQ26
Dar Es Salaam, Tanzania
was.org

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