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Juvenile giant grouper Epinephelus lanceolatus at the Cairns-based The One Company, p8.

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Zuridah Merican

2023: Caution Headwinds – How to navigate?

The recent Animal Protein Outlook for 2023 by Rabobank forecasts moderate growth but a year of change. Due to higher costs along the supply chain, margins will be squeezed for farmers and buyers will push back along with higher prices. Opportunities will be restricted and companies should recalibrate their growth expectations and plans. Salmon supply will continue to grow, but not much more, on good demand despite higher cost. More shrimp supply will come from Latin America. Feed ingredients may see some stability, but prices are unlikely to return to pre-Covid levels. How does all this affect Asia's aquaculture industry in 2023?

In summary the biggest headwind will be the gloomy economy and higher prices due to inflation and supply chain disruptions. This will affect both consumer demand and the margins on the supply side. Higher energy prices are expected to be an additional strain while the drive for sustainability will add cost to the system. This is a triple whammy. The joker in the pack is still the inscrutable China market despite recent news of reopening.

The impact on Asian shrimp is significant. The supply exceeding demand with a downward trend in prices is already here. Shrimp has a short culture cycle which makes it easy to move in and out of production, but this is only a short term relief whereby the long term solution is to increase production efficiency. Despite these threats, there remain opportunities. Covid lockdowns have created a strong retail market for Ready to Eat; Ready to Heat and Ready to Cook shrimp meals. Let us value add at source. The move to black tiger shrimp is a strength. The target is unique markets but prices have eased. Asian producers are falling behind with a lack of a sustainability story.

The continued high salmon demand offers spill-over opportunities for marine fish. How often can the consumer eat salmon in a week? This is a window of opportunity for Asian seabass. There are nice fundamentals for this fish as well as for the kingfish, said Carlos Diaz, BioMar group CEO at the TARS 2022 industry dialogue, but scale is the issue. Producers must move into the mass processed market. To meet demand from the retail markets, the production of larger fish sizes for frozen products is required. Although there is already improvement in the supply chain, there is a need for better genetics and disease management.

Freshwater fish will see a bifurcation in production. Tilapia is a good example which requires smaller fish for the local market and larger fish for export markets. Challenges vary with attention on post-harvest quality for the local market and value adding for the export market. The pangasius sector will need to review its supply chain where it is essential to improve its marketing and increase production efficiency. Vietnam's pangasius is highly price sensitive. The global economic recession will see consumers trade down i.e., choose cheaper whitefish. Will our freshwater fish be able to take advantage of this scenario?

As high feed prices will likely remain, there needs to be more focus on precision nutrition akin to that of poultry feeds and smart feeding to increase efficiency and reduce wastage. Asian feed companies will have to start paying attention to the sustainability of their feeds and feed ingredients. Life cycle assessments are coming our way and ingredients are starting to be measured in their emissions of CO_2 per kg.

The strength of any industry can often be measured by the investments and growth. The Asian aquaculture industry has seen venture capital coming in to keep innovations alive and progressing from seed to series-A stages. In the past two years, innovations have driven RAS (including round tank) technology, measuring and monitoring systems and alternative feed ingredients. The industry would like to see more focus on big data analytics, advanced nursery systems, green energy and net zero supply chains. To take the Asian aquaculture industry to the next stage, we need to focus on predictability, efficiency and 'producing more from less' along the supply chain.

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

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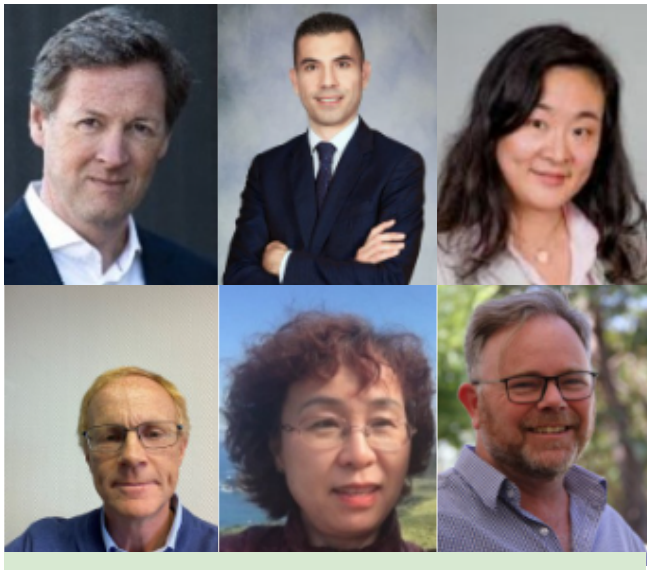
Latest insights on fishmeal and fish oil market trends



Webinar speakers, top row, from left, Petter Martin Johannessen, Enrico Bachis and Maggie Xu. Bottom row, from right, Brett Glencross , Helen Yu, Aker BioMarine, China and Jon Tarlebø, TripleNine.

IFFO's China webinar held on November 29-30, 2022, gave the latest insights on fishmeal and fish oil market trends, with specific focuses on China, Peru, Mexico and Europe.

IFFO's Director General Petter Martin Johannessen underlined the important role that marine ingredients play in supporting the growth of aquaculture as the most effective way to produce protein, with half of the raw material already certified as being responsibly sourced.

Maggie Xu, IFFO's China Director, highlighted the capacity for marine ingredients to contribute to food security moving forward. In 2020, based on FAO and IFFO data, marine ingredients contributed to the production of 7kg of fish per capita.

A resilient industry

IFFO's Market Research Director, Enrico Bachis gave an update on the latest trends in the global supply and demand of marine ingredients. A summary of the worldwide production of marine ingredients in 2021 showed how resilient the industry was in the face of the Covid-19 pandemic: production was just over 5 million tonnes of fishmeal and 1.2 million tonnes of fish oil. Around 30% of the raw material used worldwide comes from by products, confirming the ability of this sector to maximise precious raw material (see graphic on page 6).

Bachis noted that there is much interest in Peru due to its contribution of 20% of the global annual supply of both fishmeal and fish oil. The quotas for both regions have now been announced and it indicates a healthy biomass, estimated at 6,826,839 tonnes. IMARPE, the Peruvian authority, has explained that lower temperatures caused by La Nina are causing the biomass to be more spread out, which will add complexities to fishing operations and likely result in a potential catch of 1.6 million tonnes by the end of 2022, producing 20% less fishmeal and 25% less fish oil when compared to 2021 levels.

Globally, production levels in 2023 are expected to remain stable due to the positive effects of responsible management and increasing use of by products, ensuring the long-term stability of the industry.

On the demand side of both fishmeal and fish oil, Bachis highlighted how marine ingredients provide the essential omega-3 fatty acids for human nutrition, either through the farmed fish or through the omega-3 supplements consumed. The fast-growing dry petfood sector is increasingly using marine ingredients in the premium dry pet food, with inclusion rates of fishmeal at around 1 to 1.5%.

Well managed fisheries

IFFO's Technical Director Brett Glencross reported FAO's announcement earlier in 2022 that 65% of global fish stocks were considered well managed, which represented more than 80% of the global fisheries biomass. Importantly, recent studies have clearly demonstrated that when effective fisheries management is put in place, there is clear capacity to rebuild fish stocks.

Fishmeal and fish oil are both regarded as unique ingredients, Glencross noted. Fish oil provides unique and unmatched levels of EPA and DHA. Fishmeal has a near perfect balance of amino acids and provides bioactive factors.

Focus on Asia

Asia and China consume 70% of the marine ingredients used in aquaculture, but only 30% of the fish oil according to Bachis. Focusing on China, Associate Professor at Shanghai Ocean University, Wenbo Zhang, said that, the efficiency of utilising marine fishery resources in aquaculture is relatively high in China. The FIFO (Fish In: Fish Out) is only 0.25, slightly lower than the global average at 0.27 (Naylor et al., 2021). Therefore, the trend is to reduce the input of marine fishery resources in aquaculture in China.

China is a big fishmeal consumer, noted Dr Xia Fan, Executive Deputy Director of China National Feed Quality Inspection and Testing Centre in Beijing. Its domestic fishmeal production is low and high-quality feed fishmeal is imported. "It is of great significance to strengthen the safety access and risk analysis of fishmeal to promote the healthy development of feed production, animal husbandry and aquaculture in China." www.iffo.com

Investing in Asia with Lotus II fish feed factory

In November 2022, **Skretting Vietnam** inaugurated Lotus II, its new fish feed factory in Long An Province. Nearly 600 local and international guests participated in the event. The guest list included leaders of central and local authorities, representatives of key organisations, businesses, investors, customers and strategic partners in Southeast Asia and Vietnam.

Lotus II is Skretting's second aquafeed factory in Vietnam. This is an investment aimed at promoting sustainable growth – to better serve and bring mutual benefits to its customers in the region. Long An province was strategically chosen due to its proximity to the Mekong Delta, the cradle of Vietnam's seafood industry. The facility is also a key element in Skretting's strategy to develop further in Asia. Supported by its two factories in Long An province, Skretting Vietnam specialises in the production of high-quality feeds for the domestic market and for its major aquaculture operations across South Asia.

The new factory is Vietnam's most modern fish feed factory to date. Covering an area of 20,800m^2, the factory is built in the shape of a high-rise tower – a design that symbolises new heights. With a total investment of USD24 million, the factory boasts two modern production lines with a production capacity of 100,000 tonnes per year. It is equipped with a highly automated management system and features two separate production lines to manufacture different products without the risk of cross-contamination. Additionally, an ultra-fine grinding system increases the nutritional uniformity of each pellet. The factory will also produce special products in micro- and small-sizes.

Lotus II is the only fish feed factory in Vietnam equipped with advanced plasma technology for odour treatment. This system, manufactured in Canada, uses plasma jets to break down odour-producing molecules in the exhaust gas streams of manufacturing processes. Consequently, the factory's surrounding area is completely free of any unpleasant odours. This system, present in Skretting's factories in Norway, achieves an odour treatment efficiency of 90-95% without using water or chemicals. The technology not only delivers high efficiency but also saves on raw materials and resource wastage. The factory is also equipped with fully electric, emission-free forklift vehicles in line with its sustainability principles.

Skretting Vietnam said that customers and guests remarked how impressed they were with the state-of-the-art facilities and expressed their continued confidence and trust in the company.

Thanking them for their support, Nutreco Vietnam's General Manager, Eric de Vaan said, "We are delighted to welcome customers and business partners to our new fish feed factory. With Lotus II, Skretting Vietnam is now able to produce the broadest range of feeds for the widest variety of species in the country." He continued, "With this new fish feed factory, we are reaching new heights in terms of product quality, production efficiency, safety and sustainability. With this new factory, Skretting Vietnam has reaffirmed its commitment to deliver the most innovative and sustainable feeds and to bring the very latest nutritional and functional concepts to the aquaculture industry of Vietnam and beyond."

Nutreco Asia's Managing Director Jurriën Zandbergen is proud of the new state-of-the-art fish feed facility and believes it will accelerate the company's contribution to the country's sustainable aquaculture development. "We will be able to provide a wide range of feed solutions consistently. Combined with our specialty, including life start formulations, precision nutrition and technical farm management advice, we are able to improve farm performance of our customers and strengthen the aquaculture ecosystem in Vietnam."

Skretting's Innovation Director Alex Obach shared that the global production of aquatic animals has already passed 88 million tonnes and is expected to grow by another 20% in the next decade, which presents a significant opportunity for the country. "Vietnam is already one of the top five seafood producing nations in the world. Our new factory will produce innovative feed products, which when combined with our latest feeding models, farming technologies and water management solutions, will help Vietnamese farmers increase their productivity – through better growth, better feed conversion and higher survival rates. I am also convinced that through further innovation and technological development we can together overcome other challenges faced by the industry." www.skretting.com

Feedmills can now apply for certification to ASC's feed standard

In its press release on 16 January, The Aquaculture Stewardship Council (ASC) announced a new milestone with the ASC Feed Standard. From January 14, 2023, feedmills can apply for certification to ASC's Feed Standard which covers legal, social and environmental requirements for both the feed mill's own operations and for the suppliers of ingredients used in their feed production. ASC certified farms have until January 14, 2025 (24 months) to switch to ASC compliant feed to continue meeting the ASC Farm Standards.

ASC's Feed Standard tackles one of the biggest drivers of environmental and social impacts of aquaculture – the manufacturing of feed and its raw materials. More than 70% of aquaculture production (excluding algae) is dependent on feed, and it drives major environmental and social impacts of aquaculture. By requiring responsible sourcing for all major feed ingredients, ASC aims to address issues in both the supply chain and at raw material level. Requirements on reporting of performance will also improve assurances by creating unrivalled transparency throughout the entire aquafeed supply chain, as well as rewarding environmental sustainability and assisting future research into responsible feed.

Certified feedmills must source environmentally responsible marine and terrestrial ingredients. The ASC Feed Standard uses an improvement model for marine ingredients which requires feedmills to source increasingly from responsibly managed fisheries over time. MarinTrust and Marine Stewardship Council (MSC), both full members of the ISEAL Alliance, play a crucial role in this mechanism and form the key stepping stones for improvement.

The model offers a unique opportunity for feedmills to work together with their fishmeal and fish oil suppliers to meet the increasing requirements over time. Ultimately, most of the volume of marine ingredients needs to be derived from MSC fisheries.

For terrestrial plant ingredients such as soy or wheat, feedmills are required to record and report all ingredients that make up over 1% of feed and will need to take steps to ensure they have been responsibly sourced. Similarly, feedmills must also work and commit towards ensuring their supply chains are free from risks of deforestation or land conversion.

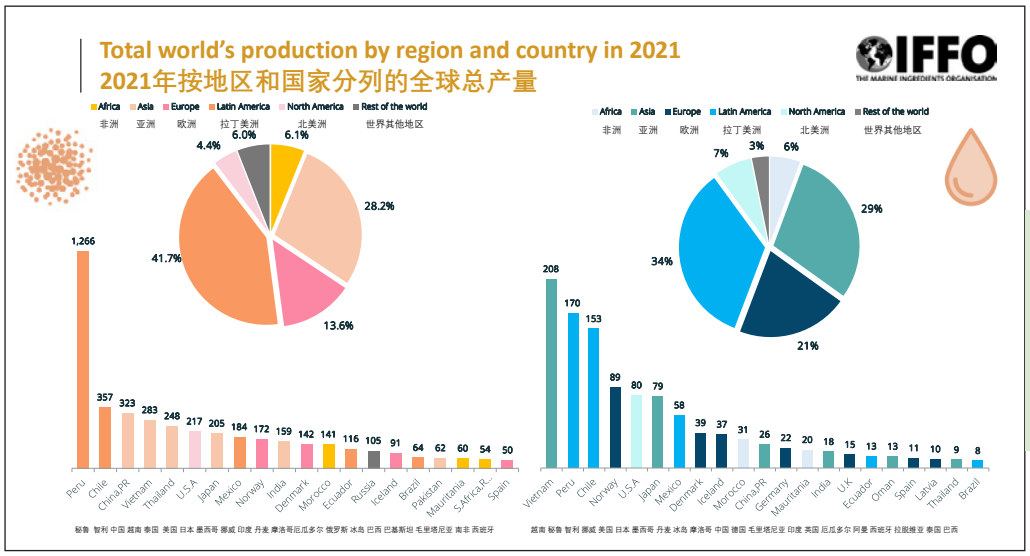
Moreover, ASC certified feedmills will have to record and report their energy use and greenhouse gas emissions and work to improve energy efficiency, use of renewables, and water usage.

Feed industry operations contribute to the economic backbone of the local communities in which they are located.

Therefore, another core requirement for feedmills is adhering to social responsibility. This includes fair treatment and wage of employees, respect of indigenous and tribal people's rights, and ensuring that no child or forced labour exists. The ASC Feed Standard includes many other social and effective management system requirements, including policies, procedures and processes for topics such as the prevention of corruption, bribery or falsification of documents.

ASC certified feedmills are also required to conduct due diligence on their supply chains to assess and mitigate these key social risks.

More about the ASC Feed Standard https://www.asc-aqua.org/what-we-do/our-standards/feed-standard/ Feedmills looking to get certified can get further details at https://www.asc-aqua.org/what-you-can-do/get-certified/get-certified-feed-mill/



Total world's fishmeal and fish oil production by region and country in 2021, presented by Market Research Director, Enrico Bachis at the IFFO's China webinar held on November 29-30 November 2022,

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Marketing Australian origin SPF grouper fry and fingerlings

With breeding technology established for three species of grouper, TCO is seeking new markets in Singapore and other parts of Asia, where there is a surge in RAS indoor farming

By Zuridah Merican

Coral trout broodstock Plectropomus leopardus . Photo provided by TCO.

Since 2016, Australia's The Company One Pty Ltd (TCO) has been supplying specific pathogen-free (SPF) grouper fry and fingerlings to sister companies (ATA) in Hong Kong and Taiwan (Epic Development Co Ltd) aside from local farms in Australia. It has also sold fry and fingerlings to Japan, Singapore, Germany and China. Singapore is an expanding market with several up-and-coming recirculation aquaculture systems (RAS) farms producing high value groupers and marine fish.

During World Aquaculture 2022 Singapore, held from November 30 to December 2, Dr Richard Knuckey, Director and General Manager, announced that TCO is now ready to explore new markets for its SPF fry and fingerlings. The company supplies 2g to 10g fry and fingerlings. "We believe that there is an increasing demand for premium SPF fry or fingerlings for RAS grouper operations where exclusion of diseases and high survival rates are vital to offset the higher operational costs of these systems. We practice a high level of biosecurity with double ozonation of incoming seawater, disinfection of eggs and the use of high-quality live feeds (algae, rotifers and copepods).

Roots in Cairns

The development of these SPF groupers has a long history. Knuckey has spent the last 20 years developing breeding technology for the groupers in Australia. Back in 1999, he moved to Cairns to work on the hatchery technology for the orange spotted grouper *Epinephelus coioides*, tiger grouper *Epinephelus fuscoguttatus* and giant grouper *Epinephelus lanceolatus*.

"The idea behind this project was to diversify away from wild capture to aquaculture. However, at the end of 2013, we had a change of government and the project was closed just when we were on the brink of commercialising the fish breeding system. With enough information, we went commercial through FinFish Enterprises with an investor. We had a farm and breeding facilities. Over three years, we had good production, but the company went into receivership. Fortunately, we could also continue the research priorities."

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The Company One facility is located adjacent to the Cairns Port and intact mangrove wetlands. It was a purpose build facility for grouper research and development and has good freight links through Cairns International Airport.

In Hong Kong, Mark Kwok established Aquaculture Technologies Asia (ATA) in 2003. In 2016, it began farming giant groupers indoors using an efficient RAS technology developed together with the Kadoorie Agricultural Research Centre, University of Hong Kong. It has the world's only self-contained, land-based grouper farm and markets the fish under its Oasis brand. ATA's production is listed as 'Green' in the World Wildlife Fund's Hong Kong Seafood Guide as a sustainable source of grouper, which has helped him sell to upscale hotels with clients interested in environmental stewardship (wwf.panda.org).

Juvenile giant grouper Epinephelus lanceolatus . Photo provided by TCO.

In 2017, Knuckey and Kwok created TCO. ATA had just started buying fingerlings from the Cairns-based hatchery and stepped in to save it.

TCO started the commercial production of the giant grouper *Epinephelus lanceolatus* fry and fingerlings in 2016. It then developed the hatchery technology for the coral trout *Plectropomus leopardus* in 2018. A recent addition in 2020 is the speckled blue grouper *Epinephelus cyanopodus*. Knuckey said, "There are some similarities in hatchery production among these species but also some challenging differences. The giant grouper was the toughest for us since the larvae are generally very weak in their early life stages. On the other hand, it was difficult to wean the coral trout onto formulated diets."

SPF status

In the case of these grouper fingerlings, they are free from nodavirus (causative pathogen of viral nervous necrosis or VNN) and iridovirus, two very important viral diseases affecting grouper aquaculture globally. TCO uses the Queensland government and private laboratories for disease diagnostics. "Over the past seven years, our fingerlings have been clear of these viruses, assuring the SPF status. OIE has listed only these two viruses in groupers. Imports into Taiwan require health certification," said Knuckey.

"These high-quality SPF fry and fingerlings are perfect for modern RAS systems where the exclusion of disease is important," said Knuckey. A testament to this requirement was confirmed by Alex Lin, Chief Scientist at ATA, who is responsible for the operation of the ATA-related company called EPIC development in Taiwan. EPIC has been importing these fingerlings for its own giant grouper farm in Taiwan. "Back in 2016, I was looking for a supply of SPF giant grouper fry. We worked together and as the fingerlings are exposed to Taiwan and Hong Kong conditions and the different strains of iridovirus, I will feedback to Richard for quality improvement."

Grow out in Taiwan and Hong Kong

EPIC imports 2g SPF fry from TCO which are then grown into fingerlings in indoor tanks. This pre-grow-out stage usually takes 85 days to produce 60-80g fingerlings in a RAS at 20-40% exchange of water. The fingerlings are then moved to a flow through system until 200-300g before stocking into the outdoor ponds where they are grown out to sizes ranging from 1.8kg to 3.5kg for different market requirements. Lin said that in indoor systems, he achieves 80-90% survival rates during the pre-grow-out phase. In Hong Kong, ATA buys fingerlings and grows them in indoor tanks over a period of 12 to 18 months for marketable sizes of 1-5kg.

During World Aquaculture 2022 Singapore, Dr Richard Knuckey (second right) with Alex Lin (second left), Anjanette Berding (left) and Dr Maximilliano Canepa (right).

"From egg to 2g fry takes up to 70 days. Our prices for SPF fry and fingerlings are much higher, but with feedback from the Australian farms indicating 90% survival to marketable fish, and after calculating production cost, our business is viable," said Knuckey. "Having partners running farms helps to stabilise fingerling production."

Lin added, "We need to change farmers' perceptions on farming. We need to make quality production predictable."

Expansion to regional markets

The current production in terms of volume and fish size is dependent on demand but Knuckey said, "Currently at Cairns, we produce a million fry/year. However, as the giant grouper broodstock produces 300 million fertilised eggs in a year, we can produce more. We have achieved a 95% hatching rate of eggs and each litre can hold up to 2 million eggs. Our target hatchery survival rate from egg to weaned fry is 3 per litre. We prefer to take orders well in advance and produce fingerlings according to demand. Following the hatchery phase, it takes 14 days in the nursery for 50mm fingerlings (2-2.5g) to 35 days for 100 mm (~20g) fingerlings."

Genetics was also a topic of discussion at the booth. Knuckey said that the giant grouper founder stocks at TCO were from the wild and that fry grow up to 20% faster than fry sourced from other regions in SE Asia.

"However, with a well-designed breeding program, there is untapped potential to further improve growth and performance. As broodstock numbers are restricted, it is not possible to undertake classical selection procedures and so we continue to work with James Cook University on the implementation of genetics selection."

He added that TCO is now working to develop autogenous nodavirus vaccines. The first vaccines for research have been used to vaccinate fish for some customers in Australia. Fortunately, there is no grouper iridovirus in Australia.

Reference

WWF, 2013. https://wwf.panda.org/wwf_news/?212133/Greener-alternatives-for-giant-grouper

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Benefits of a natural astaxanthin from microalgae in shrimp hatchery and nursery stages

These range from dark colouration, a glossy body and hard, slippery shell in broodstock to large dark hepatopancreas and excellent positive rheotaxis in PL42

By Patricio Hidalgo

There is a consensus that microalgae, part of the natural food chain, are highly beneficial as feed for shrimp health and production, especially in the early stages. This is particularly so for *Haematococcus pluvialis* which like other microalgae, contains proteins, carbohydrates, essential fatty acids, vitamins, nucleotides and minerals. However, *Haematococcus* is also a source of a complex of natural antioxidants, mainly the powerful astaxanthin. Although it is an excellent source of nutrition, a common drawback of microalgae is its higher price than non-natural alternatives.

Today there is a *H. pluvialis* producer in the Atacama Desert in Chile-Atacama Bio Natural Products S.A. This company takes advantage of its exceptional pollution-free surroundings with high light intensity and pure water from the Andes mountains, and has been able to reduce production costs by using a proprietary technology, thus narrowing the price gap and opening the possibility for extensive use. After several years of research, the company has developed a robust, state-of-the-art, culture technology of closed and open photobioreactors.

The benefits of dietary astaxanthin for shrimp range from general health improvement to specific enhancement of functions: metabolism, antioxidation capacity, effects on photo-response, stress alleviation, immune response regulation, source of provitamin A, better reproduction and brood stock quality, reduced embryonic mortality and enhanced disease resistance. There is evidence proving that astaxanthin supplementation enables efficient defense procedures against unfavourable or stressful situations.

Science-backed assessments

Astaxanthin has a fundamental role in the breeding and farming of aquaculture species and confers a significant improvement on the reproductive performance, egg production and egg quality of aquatic animals (Vassallo-Agius et al., 2001; Ahmadi et al., 2006; Paibulkichakul et al., 2008; Tizkar et al., 2013, 2015; Palma et al., 2016).

Reproductive performance and egg quality

The accumulation of astaxanthin in reproductive tissues via dietary supplementation provides a significant impact on reproductive performance characteristics, which include egg quality and quantity, hatching success and improvement on larvae quality (Pangantihon-Kuhlmann et al., 1998; Paibulkichakul et al., 2008).

Growth performance, survival, stress tolerance and disease resistance

Astaxanthin content has also been directly linked to the ability of eggs to resist extreme environmental conditions (Eisler 1957; Craik 1985; Torrissen 1990). Astaxanthin also affects stress tolerance and disease resistance of different aquatic animals.

Characteristics of natural *H. pluvialis* astaxanthin

There are three unique properties differentiating astaxanthin from this microalgae from synthetic or fermentation-origin astaxanthin. These explain the higher antioxidant power and differences in toxicology, pharmacology and metabolism (Figure 1).

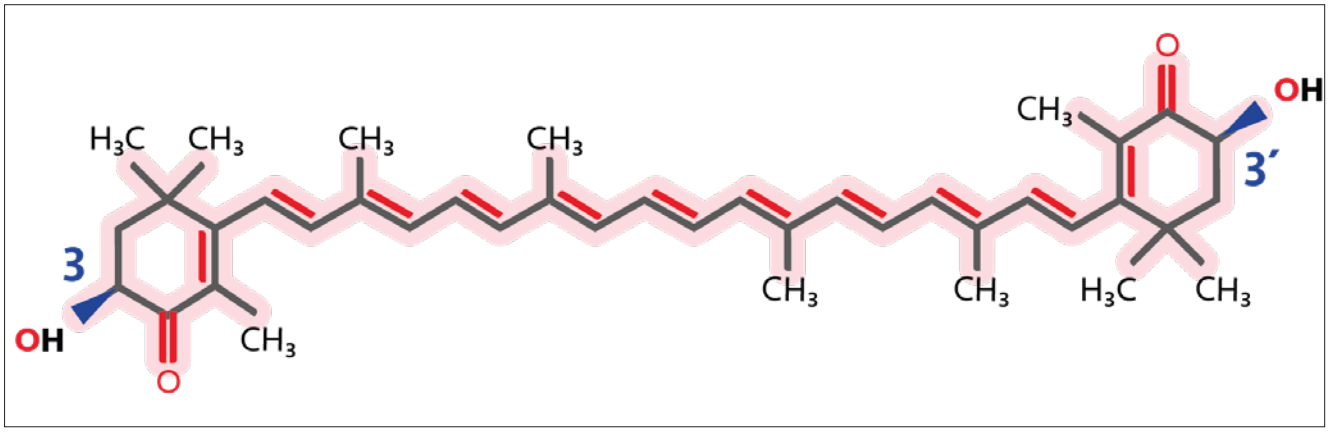

Figure 1. Image of the astaxanthin molecule from *Haematococcus pluvialis* showing its chirality.

The main chemical characteristic that explains most of the different biological responses of *H. pluvialis* astaxanthin is related to its chirality. Astaxanthin has two asymmetric carbons in the benzenoid ring where the hydroxyl groups are located. This asymmetry gives three unequal spatial configurations to the astaxanthin molecule. One of these isomers, the so-called 3S,3'S configuration, can only be sourced from *H. pluvialis*.

Chiral isomers show different biological and chemical behaviours when reacting with other chiral molecules, just as a left-hand interacts differently with left and right-handed gloves. Animal molecules such as enzymes, proteins, DNA and nucleotides are also chiral and are affected during binding and interaction with astaxanthin.

Figure 2. Healthy female broodstock resulting in active mating, better egg quality and quantity, and robust nauplii and zoea.

Due to the exposure to the intense sunlight of the Atacama Desert during its culture cycle, *H. pluvialis* reinforces its antioxidant power by up to 15% compared with other carotenoids. Cerezal-Mezquita et al. (2022) said that the main pigment is astaxanthin esters (55.13%), followed by lutein (5.67%), free astaxanthin (5.54%), β-carotene (2.76%) and canthaxanthin (2.65%). *H. pluvialis* astaxanthin is esterified with fatty acids, providing more stability and shelf life.

Experiences from industrial uses

In recent years, two major Asian companies have carried out tests at different levels using natural astaxanthin from *H. pluvialis*. Following the good results, they have scaled its use to an industrial level. These results presented in this article were obtained by using Red Meal powder 1.5% in the industrial-scale production of shrimp. Red Meal 1.5% is the brand name of a line of products developed specifically for the animal feed market, which uses the microencapsulated cracked biomass of *H. pluvialis* microalgae. The supplemented amount of Red Meal powder 1.5% in various feeds is given in (Table 1).

Diets	Broodstock	Larvae/post larvae	Nursery PL12-PL42	Grow-out
Supplementation of Red Meal powder 1.5%/kg of feed	20-40g	5g	3-5g	3-5g (14 weeks) 10-15g (5 days)

Table 1. Supplementation levels of Red Meal powder 1.5% in test diets for commercial trials.

Empirical results

In the hatchery, broodstock fed with diets supplemented with the Red Meal powder showed the following

- An excellent absorption of astaxanthin with dark colouration, a glossy body and a hard, slippery shell. The absorption is explained by the high affinity between the 3S, 3'S natural astaxanthin stereoisomer from *H. pluvialis* and the tissue cells. The enantio-selectivity of chiral astaxanthin molecules allows good binding to chiral protein molecules.
- There were no wounds after clashing. The more rigid shells and the active immune system with robust, in-condition haemocytes can quickly activate prophenoloxidase (proPO) to produce melanin synthesis involved in wound healing and enzymes of the clotting system.
- Healthy broodstock results in active mating, better egg quality and quantity, as well as robust nauplii and zoea. This difference is explained by the accumulation of astaxanthin which protects cell and mitochondria membranes from oxidation for all high-energy-consuming metabolisms (Figure 2).

Larvae and post larvae fed with diets supplemented with 5g Red Meal powder 1.5%/kg of feed using enriched rotifers or mixed over pellets showed dark colour heads, glossy bodies, strong and vigorous PL12, lipids in large dark hepatopancreas and excellent positive rheotaxis (Figure 3 and 4).

Due to astaxanthin's antioxidant action, reactive oxygen species (ROS) are quenched, thus protecting mitochondria and cell membranes from oxidative stress produced by high energy needs for rapid body differentiation and moulting during metamorphosis.

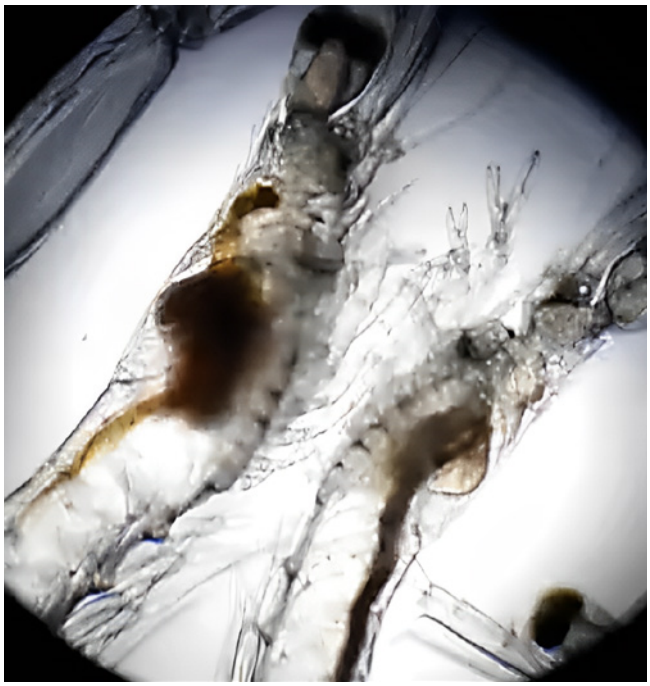

Figure 3. Larvae and post larvae with well-defined and coloured hepatopancreas produced by supplementation with Artemia enriched with astaxanthin.

Figure 4. Vigorous larvae with dark-coloured heads and excellent results in a positive rheotaxis test.

Figure 5. Notable difference in colouration after cooking of the shrimp *Penaeus vannamei;* between natural colouration with astaxanthin (above), vs synthetic pigmentation (below).

In the nursery, PL12 to PL42 fed with 3-5g Red Meal powder 1.5% per kg feed showed noticeable stress resistance to low salinity, moulting and disease. Over 90% survival at PL42 was achieved. Post larvae also showed an active, ready to work immune system. Strong and healthy haemocytes are produced abundantly by well-guarded haematopoietic tissue cells. Astaxanthin is linked and coupled to phospholipids in cellular and mitochondria membranes quenching ROS/RNS (reactive nitrogen species) that produce oxidative stress and lipid peroxidation membrane destruction.

Shrimp in the grow-out pond were also fed diets supplemented with 3 to 5g of Red Meal powder at 1.5%/kg of feed for 14 days before harvesting or with inclusions of 10 to 15g/kg of feed for 5 days. The main benefit observed was a 27+ colour on the salmon fan after cooking (Figure 5).

The high affinity between 3S, and 3'S natural astaxanthin stereoisomer and tissue proteins resulted in these positive results. Enantio selectivity of chiral astaxanthin molecules allows for good binding to chiral proteins in the crustacyanin complex.

Reference

Cerezal-Mezquita, P., Espinosa-Álvarez, C., Jáuregui-Tirado, M., Jaime-Matus, C., Palma-Ramírez, J., Ruiz-Domínguez, M.C. 2022. Physical-chemical characteristics of "Red Meal", a novel non-defatted additive in the fish feed from cracked biomass of *Haematococcus pluvialis*, Animal Feed Science and Technology, Volume 285, 115247.
https://doi.org/10.1016/j.anifeedsci.2022.115247

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Leading Asia's hatchery and nursery segments

Moving towards standardisation and data driven automation to de-risk industry and increase production efficiency.

CEO Patrick Waty (right) brings experiences along the fish and shrimp aquaculture supply chain since 2013 and Innovations Director, Dr Peter De Schryver has been with INVE since 2016.

Back in 1983, Artemia Systems NV, a spin-off from Ghent University, was the first to market Artemia. In 1991, it was acquired by INVE Aquaculture, which up to today, remains the market leader in the supply of Artemia cysts worldwide. INVE, part of Benchmark since 2016, is active in four areas; broodstock management to improve spawning, egg production and larval quality; specialised hatchery care to optimise fry and post larval robustness, survival and growth; well-balanced and cost-effective growth of fry and post-larvae in nursery, risk management and prevention at grow-out.

During World Aquaculture 2022, Aqua Culture Asia Pacific caught up with INVE's CEO **Patrick Waty**, who since 2021, leads the global team of 400+ employees. Waty joined the aquaculture world in 2013 after more than 8 years in the seafood business. His experiences range from early feeds as CEO at BernAqua; global aquafeed business development at Neovia (now ADM) and lastly as group CEO at SyAqua. **Dr Peter De Schryver**, who has been with INVE since 2016, joined the interview.

The competitive edge

What gives INVE the competitive edge in the shrimp and fish hatchery and nursery segments?

Patrick Waty attributed INVE's competitive edge to the science-based knowledge behind its founding. "We are a result of a spin-off from the University of Ghent, Belgium, more than 40 years ago. Some of the people involved were also visionaries, quick to see immediately opportunities such as in marine fish aquaculture in Europe, which was still a backyard industry back then. It needed a lot of structure." He added that it took 40 years to bring the marine fish industry where it is now in Europe.

Thirty-five years ago, there were opportunities in shrimp farming in the tropics. Waty said in the early days, the focus was to bring science into precise nutrition and formulation. They looked closely at the health aspects and nutritional needs of shrimp, started taking the impact of the environment into account, started considering bioremediation for better water quality via probiotics, etc. Our next opportunity is to replicate what we have achieved with marine fish hatcheries in Europe to tropical marine fish hatcheries here in Asia." (see page 22).

INVE became part of the Benchmark Group in 2016? What is the advantage of being in the group?

Within the Benchmark Group, which fully focuses on aquaculture, there are three divisions: Advanced Nutrition, Genetics and Health. Advanced Nutrition is only INVE and represents more than 60% of the group's activities. "Being within the Benchmark group has given INVE more visibility and more structure," said Waty, "For us, when reaching a critical size, we will need to adapt to a more corporate structure. This gives us a wider network and we have a unique

opportunity to inspire ourselves from the salmon industry, which is way ahead. It is not just copy and paste but a good source of inspiration. This is what Benchmark brings for us."

Dr Peter De Schryver elaborated on links between the different aspects of aquaculture. "We cannot have a successful performance only with nutrition. We also depend on the genetics that we are working with. So, when we bring everything together that is where we will be most successful.

"Within Benchmark there is an internal innovation board with representatives from each company working together and identifying which are the major areas of innovation. Although each of the business divisions do their own internal innovations, the innovation board is intended to support those innovations that are interesting for and require the collaboration from across the group. Dr Ross Houston is leading this innovation board."

Sustainability at the hatchery segment

In October 2022, INVE announced that it is an associate member of SSP? How important is this initiative for the business in Ecuador?

Clearly Waty is impressed by the Sustainable Shrimp Partnership (SSP), which is an excellent initiative by Ecuador's shrimp sector. Through SSP, its shrimp industry has made tremendous steps to market and differentiate its shrimp. It is adding value to the image and the quality of the product. It is not only shrimp with very good taste but the story behind them. This SSP was started at the farm level and has included processing plants.

"Last year, I talked to Pamela Nath, Director of SSP on more sustainable practices in hatcheries to further raise sustainability in Ecuador. I suggested our technology on the separation of Artemia cysts in a mechanical way with a magnet. This is a clean way of de-capsulation and a practice that has an impact on sustainability.

"We feel we can progress with this since Ecuador wants to promote healthy shrimp coming from healthy environments. Aside from this, other INVE technologies are probiotics in bioremediation to leave a clean pond after harvests."

In terms of nutrition, De Schryver said that they are on a lookout for sustainable ingredients in the formulations such as replacements for fishmeal, without compromising on performance.

What do you think of an initiative similar to SSP in the Asian hatchery segment?

Although his opinion is that Asia should also have this type of initiative, Waty advised that they should be supported by local organisations or governments. "It is not neutral if you are doing this on your own. So, I would rather see initiatives done together, such as in Ecuador, where different stakeholders from the industry, are addressing this matter."

He emphasised that sustainability is in the interest of everyone and is not just a "we are green" labelling. Initiatives should have the support of certifications such as the GLOBAL G.A.P., ASC, Friends of the Sea etc.

"Today, these addressed the segment with the biggest impact, which is farming. We should not forget that hatcheries and early stage is the pillar of success for good farming practice and therefore, this segment will be the next line of initiatives."

Markets

Among the countries in Asia, where do you have a strong presence or see a potential for expansion?

Waty's quick reply is the hatchery segment in India, where it has an excellent distributor. "We also want to be closer to customers. We have a new team in place that will introduce the Artemia SEP-*Art* technology in India. There will be new diets for the Indian market, such as nutritional flakes and boosting flakes. We feel that these solutions are required in India, which is facing some challenges and I expect these initiatives to help India ride the storm."

Peter De Schryver and Tania De Wolf with the prototype Artemia Counter which separately counts cysts, umbrella, instar I and instar II. It has an accuracy rate of more than 98%.

What have been your game changers for Asia?

There is the decapsulation technology, Artemia SEP-*Art* introduced in 2009. The team noted that INVE is investing more into an approach of more efficient production of live food.

"For us, it is not just products, but protocols and standing close with our customers in getting them to be more efficient. Our technical support part of the company is so important for us," said Waty.

At this World Aquaculture 2022, the company presented a prototype of a new device for more automated counting of Artemia and rotifers, which will increase the efficiency of hatcheries with less labour, higher accuracy and improved protocols. De Schryver explained, "This automated counter gives the possibility to evaluate the status of Artemia cyst hatching very quickly, with an accuracy of more than 98%.

"It will allow hatcheries to have more control over cyst hatching. In a matter of seconds, our counter can determine the number of cysts, umbrella, instar I and instar II stages. It will be an interesting tool for them to make sure that they can get the highest quality out of the products that we are offering them. For the hatchery, the value here is that instar I has a much higher nutritional value than instar II. So, if a hatchery technician is using instar II, it is a lower quality product, but it has the same cost."

Waty added, "Achieving more precision farming and feeding and bringing more standardisation into our industry will be a game changer. We do not need to be rigid, but we need to have more standards in what we are doing. This starts with standardisation in water quality (pH, temperature, nitrate etc) as it is the environment where our animals are living. We need to set norms for each species, culture system etc. For the moment, we are still going the empirical way."

Is there a particular region or segment which has been particularly challenging?

"We are geographically well spread and therefore, no market is particularly more challenging than another. For me, the most difficult segment to address is tropical marine fish species. This is because this industry is not as structured as that in Europe yet. It makes it more challenging to know where to start and to whom we should speak to make changes" said Waty.

In your opinion, what should the shrimp industry in Asia focus on?

This is overall efficiency, said De Schryver. "We need to have a higher degree of standardisation, knowing what we are doing. Now it is very fragmented with different practices from region to region. But we need to collaborate as an industry; the farmers, producers and suppliers need to make that connection and work together. We should not just use products and see how it works and do it in an empirical way but collaborating really towards a more knowledge basis."

The INVE Aquaculture team at World Aquaculture 2022 Singapore which was held from November 30 to December 2.

Waty believes in convenience, automation and standardisation. “Sometimes, by standardising protocols, you will make the life of the hatchery technicians much easier. Now, protocols are still too complicated. When we have innovations towards the direction of convenience as well, it will be easy to use and easy to replicate.”

De Schryver echoed, “Today, we should focus on what we have and improve on them. We cannot just rely on the creation of silver bullet solutions for problems such early mortality syndrome (EMS) and *Enterocytozoon hepatopenaei* (EHP) when we think of diseases. We need to work at other levels at the same time.”

From a welfare point of view, there is a lot of interest by consumers and others in the industry with regards to broodstock ablation. The whole genetic program with Benchmark is based on non-ablated females. Therefore, within Benchmark, the Genetics and Nutrition groups need to collaborate to see the effects of moving away from ablation.

“There is a need to further study how this non-ablated approach can be further optimised, for example through improved nutrition, to provide even better quality products to the farmers,” said De Schryver.

What are the changes needed for a better hatchery and nursery segment?

Over the next 5 years, the list is standardisation on water quality, automation, convenience and focus on de-risking the industry.

Waty reiterated on his dream on standardisation, that the water discharged from tanks is as clean as it went in. “We want to bring those standards, to bring this transfer of knowledge and to help this tropical marine fish to grow. We need more automation and convenience. The latter is the convenience of SOPs and having products close to the hatcheries.”

There is a need to find ways to de-risk the high-risk hatchery segment. “As much as possible, we need to remove all the risk factors by adopting some protocols.” said Waty.

“With regards to broodstock, I question the practice by the hatcheries and the governments favouring specific pathogen free (SPF) broodstock. As I see it, in shrimp hatcheries, at the very first moment the SPF broodstock is in a hatchery, it loses its status of SPF because of feeding with squids, polychaetes and sandworms.”

When nurseries are added, it is increasing the efficiency with more robust animals and ensuring more cycles in the farm. INVE encourages this practice and has excellent solutions.

De Schryver explained, “Our raceway solutions are a combination of optimal and booster diets to make shrimp stronger at specific periods such as at the point of transferring from one stage to another. There are probiotics to keep optimal water quality, digestion of waste and contribute to feed assimilation. For us, the combination of all of the above is most important.”

The target of automation is enhanced efficiency of live food production. De Schryver strives for automation at the production level in the tanks to increase efficiency in hatcheries. Knowing the biomass of live food and the requirement of the fry or larvae, is an efficient way to avoid overfeeding and underfeeding. The purpose is also to maintain optimal water quality.

“At INVE, the driver is our customers’ efficiency. We are customer-centric and if our customer is successful, it means that we will also be successful,” concluded Waty.

Working with marine fish hatchery technology in Singapore

On November 30, Singapore Food Agency (SFA) and INVE Aquaculture signed an MOU to jointly set up a SFA-INVE Hatchery Technology Centre at SFA's Marine Aquaculture Centre (MAC) on St John's Island. The proposed centre will bring together SFA's expertise in hatchery design and production for tropical marine species (e.g., Asian seabass *Lates calcarifer* and red snapper *Lutjanus* spp), as well as INVE's in-depth knowledge on specialised fish nutrition for early developmental stages, including its patented technologies for live feed.

Waty elaborated on the origins of this MOU. "Over the the pandemic years, we were able to build an outstanding network together with SFA. The facilities at MAC opened my eyes. So, I said to myself that this is a real opportunity for a company which is ready to transfer knowledge. In the first month after joining INVE in 2021, I was already addressing this matter with Peter, who oversees R&D and Innovation. We decided that we must open ourselves to Singapore and the region; open our books and our knowledge, transfer this knowledge because if we keep the science just for us, it will not work."

The advantage at MAC is the excellent facilities, well maintained with different systems from a hatchery until grow out and a live feed section, culturing rotifers, Artemia and microalgae. A unique opportunity is the excellent knowledge of Asian seabass as well as for other marine species. Some breakthroughs are on the way by adapting its protocols and products to tropical fish species. This will increase efficiency, survival rates and reduce deformities.

"We are using the knowledge that we have on the Mediterranean fish species and we are going to transfer this knowledge to some tropical fish species. It is not only to improve on our knowledge but to create more synergy. It is not just with our local interactions but for the region. Singapore has its '30 by 30' goal but also wants to be a reference point for the region. This is also an ambition of INVE," said De Schryver.

The MOU includes the setting of a hatchery centre to demonstrate the latest technologies as well as specific hands-on training. This will be conducted by INVE's technical support team. "This is where I think we can play a role by opening these doors because we have the customer base. If we want those customers to be more efficient and follow new protocols and new practices, we want them to visit these facilities," said Waty.

The MOU was jointly signed by Chan Hian Lim, Deputy Chief Executive Officer (Corporate, Industry, and Technology) of Singapore Food Agency and Patrick Waty, Chief Executive Officer, INVE Aquaculture.

"In the future, we will identify joint research projects, on topics of benefit for all -SFA, INVE and for the region," said De Schryver. "We believe in collaboration; we are also open to collaborate with others from the industry. We believe that when we all work together, we can benefit the industry. We truly want also to use this initiative to broaden our network and to broaden our collaborations overall."

Waty justified, "We need to recognise marine fish species here are not the same as those in Europe. Therefore, we must do this R&D innovation very close to the market."

Black soldier fly meal and oil as functional ingredients for marine shrimp

There is resistance to *Vibrio parahaemolyticus* with better survival rates and a better condition of the hepatopancreas.

By Piet Verstraete, Niti Chuchird, Cameron S. Richards, Stefanie Möller, Franck Ducharne and Romain Ménard

Much has been said and written on the potential of insect products as a sustainable alternative to marine ingredients in aquafeeds and inevitably, questions are raised on the production volumes and price positioning of commercially available insect meals and oils. In this article, we focus on what we know on the functional properties of black soldier fly (BSF) meal and oil. However, we focus specifically on Entomeal and Entolipid, produced by Veolia Bioconversion, Malaysia and the potential benefits of these products for the aquafeed industry. We also report on a demonstration of this potential for *Penaeus vannamei*.

General benefits of BSF meals and lipids

The main general benefits of Entomeal and Entolipid are summarised in Figure 1. Some of these benefits are unique and can add significant value to feed formulations.

Most important is that the time between harvesting the BSF larvae and processing the finished products (oil and meal) does not exceed 8 hours. This fast processing leaves no time for product degradation by microbial spoilage and oxidation. The protein freshness is confirmed by very low values for total volatile nitrogen (TVN) (maximum 25 mg/%) and histamine (maximum 10ppm) in the meal. Oxidation of the lipid in Entomeal and Entolipid is limited, with typical POV values below 5meq/kg fat and a Totox of less than 20. FFA values are typically lower than 6%.

The BSF larvae are reared in a controlled environment and fed GMP+ certified feedstocks, negating the risk of contamination with undesirable substances. This contrasts with products harvested from the sea or the land. As a result, mycotoxins, pesticides, antibiotics and PCBs/dioxins are absent in the products and levels of heavy metals are well below the maximum levels for feed ingredients as determined by the European Union (EU Directive 2002/32/EC).

Potential effects on the immune system and disease resistance

One of the most interesting potential functionalities of this insect meal and lipid is related to the natural defense system of insects. Insects lack an adaptive immune system, meaning they are unable to synthesise antibodies. Consequently, they have developed a number of antimicrobial pathways to help protect against pathogens. More than 150 peptides with antimicrobial activity (antimicrobial peptides or AMPs) have been identified as part of the natural defense system of insects (Yi et al., 2014) and at least 57 AMPs have been identified in BSF (Moretta et al., 2020).

AMPs exhibit an antimicrobial effect by disrupting the microbial membrane via different mechanisms such as the formation of ion channels or transmembrane pores (Duclohier, 2002; Park and Hahm, 2005; Józefiak and Engberg, 2016). These mechanisms are far more robust than the antimicrobial mechanism e.g., antigens, found in other animals and significantly reduce the ability of microbes to develop resistance. For this reason, AMPs are being studied as an alternative to antibiotics (Wang et al., 2016; Auza et al., 2020) in animal feeds and offer a potential value-add for Entomeal.

An additional potential lies in the specific amino acid composition of the BSF meal. Although the amino acid profile shows lower levels than fish meal for methionine and lysine, the meal is rich in other essential amino acids:

- Histidine (3.02% of the protein, versus 2.04% of the protein in fish meal), which plays an important role in smoltification of salmon and in osmoregulation (Waagbo et al., 2010; Brack et al. 2005).
- Threonine (4.18% of the total protein versus 3.82% for fish meal), which is important for mucus formation of fish under stressful conditions (Eddy and Fraser, 1982).
- Tryptophane (1.95% of the total protein versus 0,76 % for fish meal), which is important for animal stress reduction through the synthesis of serotonin in the brain (Winberg et al., 2001; Lepage et al., 2002; Hseu et al., 2003; Hoglund et al., 2005, 2007).

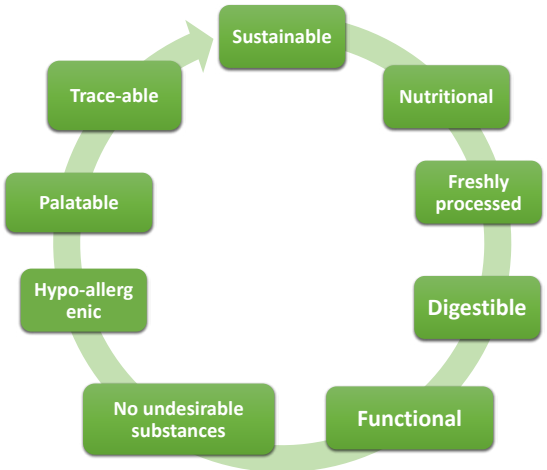

Figure 1. General characteristics of Entomeal and Entolipid.

Some unique properties emerge from the lipid analysis; a high percentage of medium chain fatty acids (MCFAs). MFCAs are rapidly absorbed from the gut and transported directly to the liver, where they undergo fast oxidation and provide a readily available energy supply. This is contrary to long chain fatty acids, which must undergo more complex metabolic pathways.

The main MCFA in Entomeal and Entolipid is lauric acid (C12:0) which is up to 28% of total fatty acids. Lauric acid can only be found in BSF (but not in other insects), coconut oil, palm oil and mammalian milk. Lauric acid is rapidly absorbed and oxidised resulting in an energy boost, which potentially helps to overcome stressful events. Also, anti-bacterial, anti-fungal and anti-viral effects have been reported for lauric acid (Liebermann, 2006).

Additionally, the BSF meal contains about 5% chitin which is of a similar type of α-chitin as in the shrimp (Soetemans et al., 2021). Chitin is a major constituent of the exoskeleton of crustaceans and insects, and is known for stimulating innate immune cells (Lee et al., 2008) and improving disease resistance by reducing pathogen growth (Bruni et al., 2018).

From theory to practice: An evaluation of functional effects on *Penaeus vannamei*

To verify the performance and potential functional properties of Entomeal and Entolipid a trial was set up at the Aquaculture Business Research Center, Kasetsart University, Thailand.

The experiment was set up in three steps:

- A growth phase with blood sampling for evaluation of the immune response,
- A digestibility trial,
- A challenge test using *Vibro parahaemolyticus*.

The experimental conditions are summarised in Table 1.

Performance	Challenge test	Digestibility
DOC 45 Stocking PL12 SD 160PL/m³ 500L tank 80 PL per tank n=4 feeding to satiation Salinity 25-30ppt	*Vibrio parahaemolyticus* DOC 7 Juveniles 150L tanks n=4 per treatment 30 juveniles per tank	DOC 14 Juveniles 20 500L tanks 40 juveniles per tank

Table 1. Overview of the trial set-up.

	Control	Tr1	Tr2	Tr3	Tr4
Entomeal	0%	2%	5%	10%	2%
Entolipid	0%	0%	0%	0%	2%

Table 2. Overview of the different treatments.

One control feed without insect products and three different levels of Entomeal were evaluated (Tr1-Tr3). A fourth treatment was formulated with the inclusion of 2% Entolipid on top of 2% Entomeal (Table 2).

Test feed formulations

The control feed was based on a typical commercial feed formulation for *P. vannamei* and all diets were prepared using common commercially available ingredients. The test feeds were formulated to obtain the same levels of crude protein (37.2%), crude lipid (7.83%), and crude starch (16.9%), resulting in similar levels of total energy in the diet (Table 3).

The trial feed concept was based on formulating optimal diets to express the potential functional properties of the meal and lipid products. Good quality fish meal and tuna liver meal were partially reduced, without aiming for a 1:1 fishmeal substitution. Other key nutrients such as, methionine, lysine, cholesterol and phospholipids* were balanced at the same level as the control diet (Note: phospholipids could not be balanced for 2% Entomeal+ 2% Entolipid treatment without compromising, iso-lipid/ iso-energy levels).

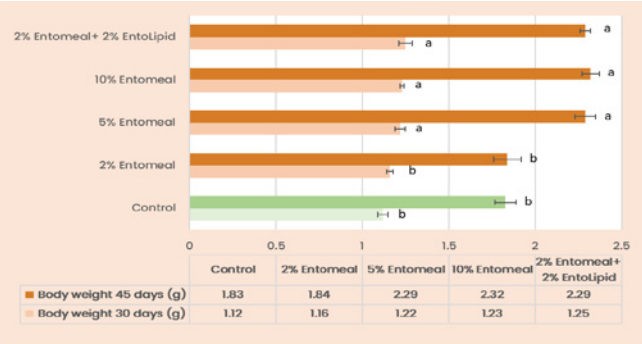

Figure 2. Average body weight after 30 and 45 days. Values (mean ± standard deviation) with different letters are significantly different ($p<0.05$).

Performance trial (45 days from PL12)

Survival rates after 45 days, ranged from 78.13% for the control group to highest survival rate at 82.50% for the group fed the Tr3 treatment diet with 10% meal. There was no significant difference in feed intake of shrimp from all treatments.

Shrimp fed the diets Tr2 and Tr3 with 5% and 10% of the meal and diet Tr4 (2% each of meal and lipid) had significantly higher body weights (after 30 and 45 days of feeding) than the control group and diet Tr1 (2% meal, Figure 2).

After 45 days of feeding, feed conversion ratios were significantly better for the diets Tr2 and Tr3 (with 5% and 10% meal) and diet Tr4 (2% meal+2% lipid) as compared to the control and diet Tr1 (2% meal, Figure 3). Protein efficiency ratios (PER) were significantly better for the Tr2, Tr3 and Tr4 diets compared to the control and diet Tr1 (2% meal). The Tr2 diet showed the highest protein efficiency ratio (Figure 4).

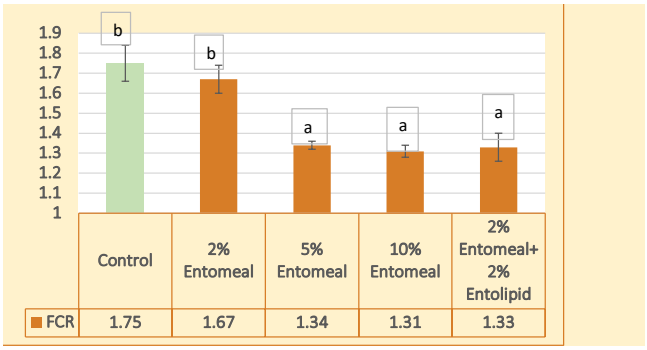

Figure 3. Average feed conversion ratios (FCR) after 45 days of feeding. Values (mean ± standard deviation) with different letters are significantly different ($p<0.05$).

	Ingredient (%)	Control	Tr1	Tr2	Tr3	Tr4
Fish meals	Fishmeal 60%	9.53	9.53	9.04	6.64	9.53
	Fishmeal 65%	2.38	0.97	0.00	0.00	0.97
Marine meals	Mixed marine meals	12.25				
	Tuna liver powder	2.38	0.95	0.00	0.00	0.00
Animal protein	Poultry meal 64%	11.32	11.32	9.29	7.10	11.27
	Insect meal	0	2	5	10	2
Oils & fats	Insect oil	0	0	0	0	2
	Fish oil tuna	0.25	0.14	0.17	0.25	0.11
	Lecithin	2.14	2.21	2.28	2.41	1.43
	Cholesterol	0.000	0.006	0.016	0.030	0.006
Plant products	Soybean meal	21.85	21.55	23.89	23.97	23.63
	Fermented soybean	3.57	5	5	5	5
	Wheat flour	19.05	18.75	18.28	19.31	22.67
	Wheat grain	3.89	3.83	3.74	3.94	4.63
	Rice bran full fat	6.91	7.00	6.48	4.45	0.00
Additives	Lysine	0.18	0.19	0.24	0.31	0.20
	Methionine	0.204	0.213	0.234	0.250	0.220
	Premixes& additives	4.09				

Table 3. Overview of the formulations used for the control diets and the experimental diets using Entomeal and Entolipid.

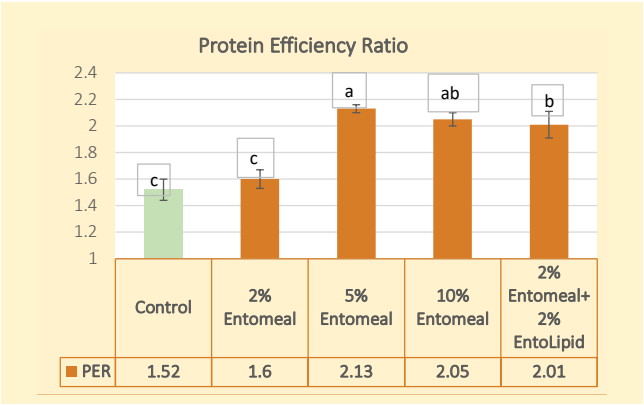

Figure 4. Average protein efficiency ratios (*PER*) after 45 days of feeding. Values (mean ± standard deviation) with different letters are significantly different ($p<0.05$).

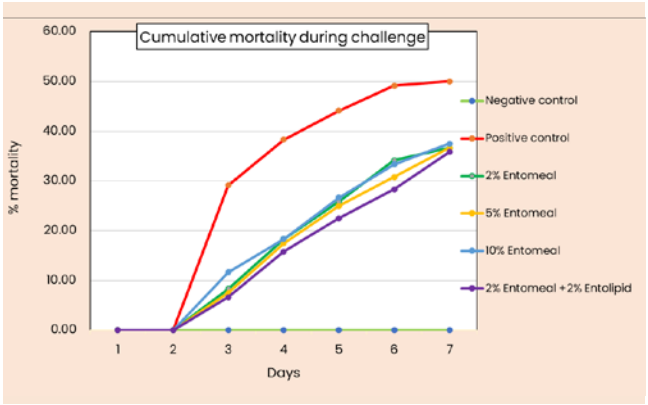

Figure 5. Cumulative mortality during challenge with *Vibrio parahaemolyticus*.

Blood parameters and immune response

The results on immune response of shrimp fed with different diets are summarised in Table 4. These include the total haemocyte count, phagocytosis activity, phenoloxidase activity, superoxide dismutase activity and bactericidal activity. Shrimp from all groups fed diets with insect products (Tr1-Tr4) showed significantly higher immune responses than the control group.

Challenge tests

The average cumulative mortality rate of shrimp during the 7-day challenge test with *V. parahaemolyticus* at the dose of LD50, is shown in Figure 5.

All treatments showed a significantly higher average survival rate after 7 days of challenge as compared to the positive control (the control diet without any insect products but also challenged with *V. parahaemolyticus*). Additionally, shrimp from all treatments showed a significantly higher average body weight increase during the challenge period as compared to the positive control group.

Histology of the hepatopancreas of shrimp before and after the challenge test with *V. parahaemolyticus* is presented as Figure 6.

The hepatopancreas of shrimp from all study groups before the challenge test and the control group without *V. parahaemolyticus* (after the challenge test) showed normal histology without indicating any pathogen infection.

In contrast, histology of the hepatopancreas of shrimp challenged with *V. parahaemolyticus* revealed a sign of sloughing off the hepatopancreas cells typical of white faeces syndrome. However, shrimp from the Insect meal group showed a better condition of the hepatopancreas cells than the control group challenged with *V. parahaemolyticus*. They had fewer signs of sloughing hepatopancreas. This information coincides with the survival rate of shrimp after a challenge trial.

Results from the digestibility trial

The Tr4 diet which had 2% inclusions of both meal and lipid had a significantly higher protein digestibility than all other treatments and the control. There was no difference between the protein digestibility of the diets with 10%, 5% and 2% inclusions of the meal. The protein digestibility from these three treatments was significantly higher than the control group. (Table 5). No significant differences in lipid digestibility were detected for the different treatments. The Tr4 diet had a significantly higher dry matter digestibility, followed by the control group and the rest of the diets with meals included.

At the same time, the Tr4 diet had significantly higher organic matter digestibility than all other groups. The organic matter digestibility of diets Tr3 and Tr1 were significantly higher than the control group, and the group provided 5% of Entomeal.

The Tr4 diet (with both meal and lipid at 2%) had significantly higher apparent digestibility for nitrogen-free extract than all other groups. There was no difference for digestibility of nitrogen-free extract for all treatment diets containing the meals only.

Blood parameters	Total haemocyte count	Phagocytosis	Phenoloxidase	Superoxide dismutase	Bactericidal activity
Units	**10^6 cells/mL**	**%**	**units/ min/ mg protein**	**% inhibition**	
Control	2.49±0.09^b	59.50±0.64^b	238.90±14.66^b	60.29±1.39^b	1:4
2% Entomeal	2.98±0.55^a	72.00±1.44^a	300.68±18.62^b	67.57±1.36^a	1:16
5% Entomeal	2.88±0.21^a	71.83±1.14^a	281.93 ±19.60^a	65.69±1.16^a	1:16
10% Entomeal	2.80±0.14^a	71.00±1.15^a	278.54±14.36^a	65.44± 2.10^a	1:16
2% Entomeal+ 2% Entolipid	2.99±0.01^a	72.50±1.14^a	301.43±13.66^a	67.39±1.79^a	1:16

Table 4. Results for the control and different treatments on blood parameters related to the immune status of *Penaeus vannamei* after a 45-day growth trial. Values (mean ± standard deviation) in the same column with different letters are significantly different ($p<0.05$).

Apparent digestibility	Control	2% Entomeal	5% Entomeal	10% Entomeal	2% Entomeal +2% Entolipid
Dry matter digestibility (%)	67.07±0.11^{d}	66.84±0.17^{b}	63.01±1.15^{e}	65.83±0.10^{c}	79.57±0.11^{a}
Organic matter digestibility (%)	78.68±0.40^{c}	79.73±0.32^{b}	78.09±0.24^{d}	79.39±0.35^{b}	87.85±0.21^{a}
Lipid digestibility (%)	90.29±2.86^{a}	90.52±5.26^{a}	90.83±5.10^{a}	91.55±6.41^{a}	93.87±2.55^{a}
Protein digestibility (%)	79.45±0.10^{c}	81.97±0.11^{b}	81.26±0.12^{b}	82.07±0.11^{b}	88.49±0.06^{a}
Nitrogen free extract (%)	87.05±0.53^{b}	83.61±0.80^{c}	84.60±1.56^{c}	83.92±0.92^{c}	90.93±0.36^{a}

Table 5. Apparent digestibility of the control diet and diets with inclusion of Entomeal and Entolipid for *Penaeus vannamei*. Values (mean ± standard deviation) in the same column with different letters are significantly different ($p<0.05$).

Conclusions

The inclusion of Entomeal and Entolipid improved the performance of a standard commercial formulation for *P. vannamei* during a 45-day feeding trial, as demonstrated by a greater average body weight and reduced FCRs obtained with diets including BSF meal at 5% and 10% and BSF oil at 2% meal on top of 2% of meal.
Overall, inclusion of the BSF meal and lipid had a positive effect on the digestibility of shrimp feed produced with a typical commercial formulation.

Blood sample analysis together with survival, and histological observations after challenged with *V. parahaemolyticus*, provide an initial lab scale confirmation of the potential functional properties of Entomeal and Entolipid for *P. vannamei*. The immune status of shrimp fed diets containing the BSF meal and lipid improved after 45 days of feeding and the shrimp were more resistant to *V. parahaemolyticus*, resulting in better survival rates, and a better condition of the hepatopancreas after being challenged with the pathogen.

References are available on request

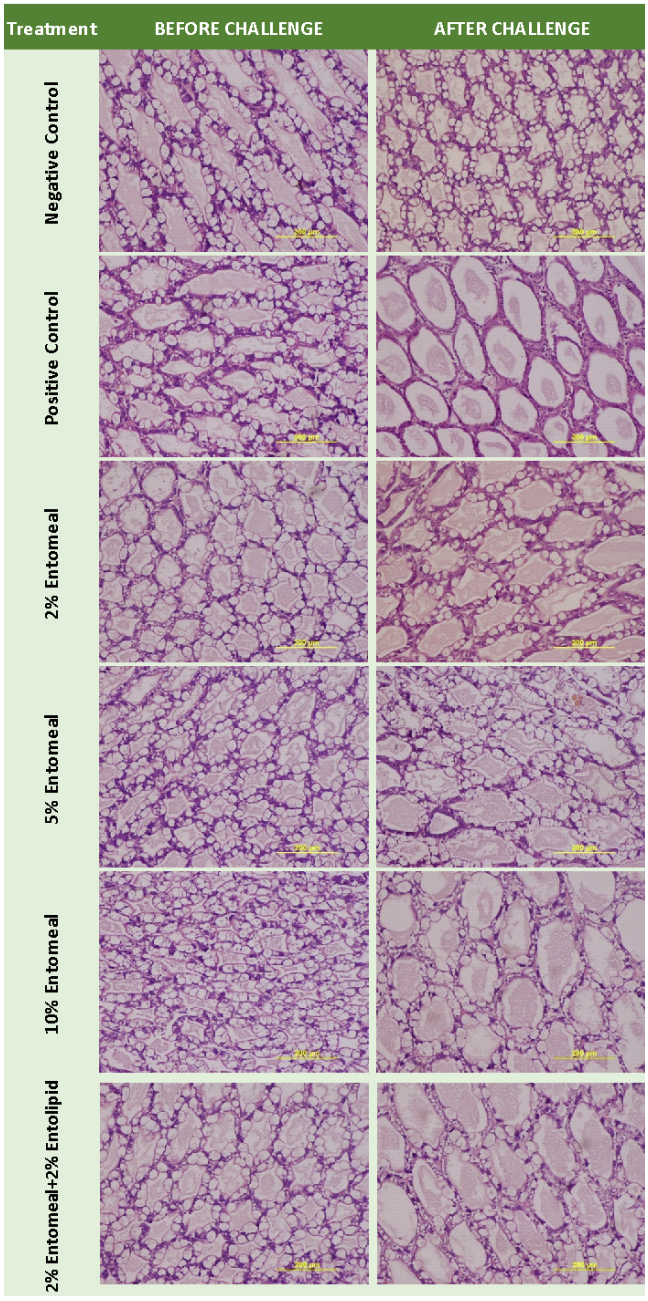

Figure 6. Histology of the hepatopancreas before and after challenge with *Vibrio parahaemolyticus*.

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Demonstrating cost reductions with krill meal without comprising growth performance

As shrimp feed millers continue to face rising prices for major ingredients, the challenge for them is in managing formulation costs. During World Aquaculture 2022 Singapore, held from November 30 to December 2, Aker BioMarine's Dr Lena Burri, Director R&D, Animal Nutrition and Health, and Atul Barmann, General Manager, Aker BioMarine India, explained some of the recent initiatives the company has been developing to help the industry cope with the user demand to have reductions in formulation costs without compromising on feed performance.

"The issue is replacing the most expensive protein sources with alternatives. Soybean meal, soybean concentrates, fermented soybean meal or alternatively poultry by product meals are currently the most common options adopted by Asia's aquafeed players to partially replace fishmeal and bring down formulation costs. Feed millers are also looking at unconventional sources such as insect meals and single cell proteins," said Barmann. "A serious consequence is the reduced attractability when replacement is with terrestrial protein sources. Therefore, we propose the addition of krill meal to solve this problem. As a start, we looked at shrimp feed formulations. Using Ecuadorian ingredient prices, we know that there are feed cost reductions just by reducing fishmeal and supplementing with krill meal."

Burri updated on research efforts for QRILL Aqua in several areas – to understand the mechanisms of dietary krill meal in shrimp and fish farming. The most recent activity is a review article which explores various protein sources including that of krill meal. "Such information guides feed millers on getting the most from their protein sources, reducing the most expensive item which in shrimp diets is actually fishmeal."

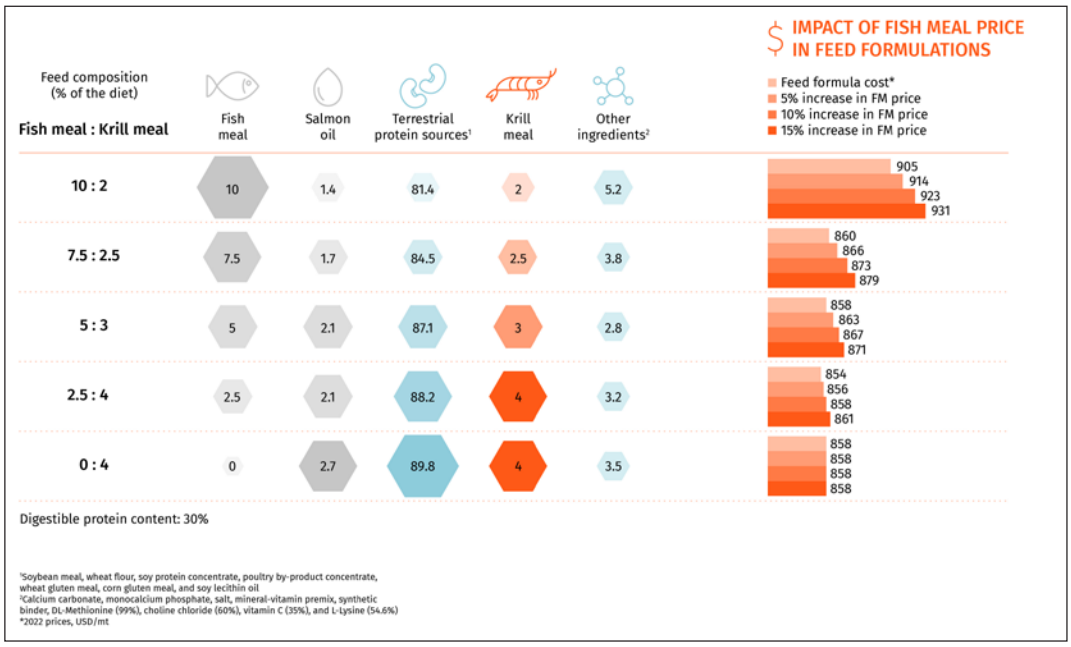
The latest review paper by Instituto de Ciências do Mar, Brazil (Labomar) and the Aker BioMarine team emphasises the need to address the risk for missing essential nutrients in dietary feed formulations for shrimp. Krill meal, as a functional feed ingredient, has shown through previous research that it can improve attractability, palatability and general health in shrimp.

The Aker BioMarine team sees a need for feed millers to replace fishmeal with alternative protein sources smartly and use krill meal cost-effectively in the formulations. It is also to reduce the reliance on fishmeal. A study with the Pacific white shrimp *Litopenaeus vannamei* showed that a diet with 3% krill meal was most effective in increasing shrimp growth, as compared to diets supplemented with some of the most common attractants used by the shrimp feed industry.

Reducing formulation costs

Barmann said, "The need of the hour is reduced formulation costs. There are several permutations presented to visitors in a chart at this trade show, in terms of ratios of fishmeal: krill meal, where fishmeal is replaced by terrestrial protein sources. This was drawn up using price data on feed ingredients from Ecuador."

Formulation costs for a feed with 30% digestible protein with increases in fishmeal prices from 5% to 15% were calculated. Based on 2022 prices, the highest formulation costs are at USD931/tonne when the fishmeal is included at 10% and krill meal at 2% and fishmeal has a 15% price increase. In comparison, the formulation cost for 5% fishmeal and 3% krill meal feed ranges from USD858/tonne to USD871/tonne, based on the assumption that fishmeal prices go up by 15% for the latter. The team concluded that the replacement of fishmeal with alternative protein sources and krill meal can reduce the economic impacts of fishmeal fluctuations.



A solution for antibiotic-free shrimp farming

A new alternative to antibiotics in shrimp farming is a feed additive using novel nanobiotechnology from Taiwan's NTOU

By Eliza Lin, Amanda Kuo and Binesh Unnikrishnan

Shrimp is a premium seafood widely consumed in many countries regardless of religion, race and ethnic groups. More than 6 million tonnes of shrimp are consumed worldwide each year. In order to meet the needs of consumers around the world, and also to avoid the depletion of the natural environment due to overfishing, the development of shrimp aquaculture technology continues to play an important role. Since Dr I Chiu Liao, an academician of the Academia Sinica in Taiwan, first developed the artificial culture of the black tiger shrimp in 1968, the global output of farmed shrimp has officially surpassed that of caught shrimp since 2007. Today, shrimp farming has developed into a huge industry with an annual output value of about USD100 billion globally.

However, this huge aquaculture industry is currently suffering from several major threats. Among them, infectious diseases are particularly harmful to the globalised high-density shrimp farming model. The acute hepatopancreatic necrosis disease (AHPND) outbreak which started in 2010 on a small scale in China and Vietnam and within 3 years caused a global pandemic. According to FAO, AHPND cost the global shrimp industry more than USD44 billion from 2010 to 2016 alone.

In many countries, in the past, antibiotics have been used to prevent infectious diseases in shrimp. But after years of indiscriminate use, it has led to an epidemic of drug-resistant bacteria. On one hand, the effect of antibiotics gradually becomes ineffective; on the other hand, it also causes environmental pollution and even threatens human health. Therefore, countries around the world have strengthened the supervision of antibiotic use and antibiotic-free farming has become an international trend.

Antibiotic replacement products currently on the market include phytobiotics, probiotics, organic acids and antimicrobial peptides. However, these products are still inferior to antibiotics in terms of convenience, stability, protective effect and price, so the market still cannot completely eliminate the dependence on antibiotics. According to statistics, the current global market for animal antibiotics is as high as USD4.5 billion per year.

An alternative to antibiotics

A research team from the National Taiwan Ocean University (NTOU) recently proposed a new technology, which can be said to be a perfect alternative to antibiotics and can also provide efficient protection for farmed shrimp. Led by Professor Han-Jia Lin and Professor Chih-Ching Huang, the team has developed a technology based on "therapeutic carbon nanomaterials". In this cross-generational study, it was found that through a series of techniques similar to Chinese herbal medicine processing, the antibacterial ability of natural ingredients can be greatly increased by 2,500 times, without causing drug resistance, but at the same time, maintaining the biocompatibility and safety of natural ingredients.

In this series of studies, the NTOU team have developed many new materials with excellent antibacterial, antiviral, anti-inflammatory and other effects. So far, more than 20 top-tier papers have been published, with more than 400 citations. Among them, two studies have applied this technology to the prevention and treatment of shrimp infectious diseases such as white spot disease (WSSV) and AHPND. The results confirmed that these materials can actively block the spread of bacteria, improve the immune system, neutralise toxins, etc. In the long term, the product will not affect animal health, nor will it affect the balance of intestinal bacteria (Yen et al., 2021).

Pathogen	Survival rate (%)			Production increase over control (times)
Vibrio parahaemolyticus	Batch 1	Control	28.6	3.19
		Prawn Balance	91.4	
	Batch 2	Control	33.3	2.88
		Prawn Balance	96.2	

Table 1. *Vibrio parahaemolyticus* challenge test to simulate the survival rate of severe infection.

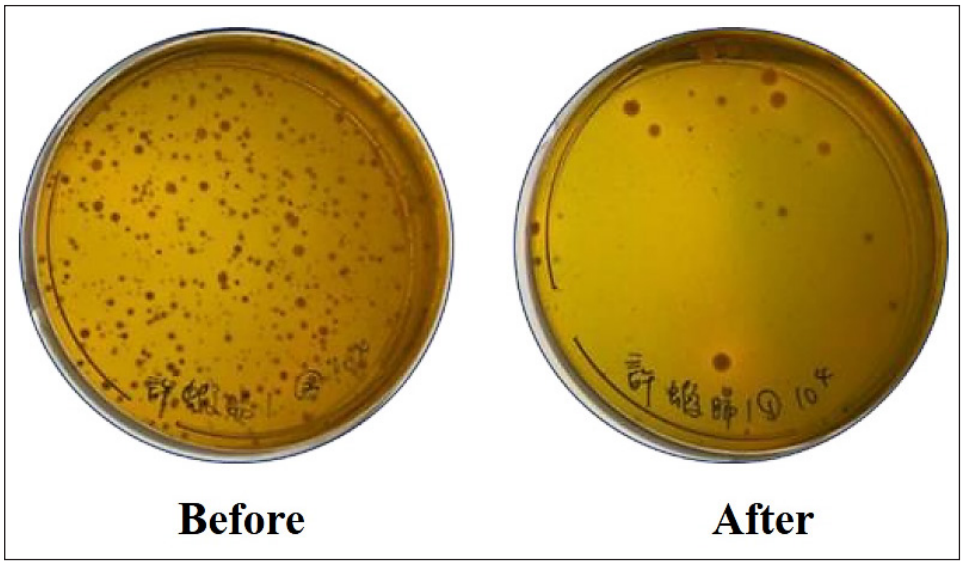


Figure 1. With dietary supplementation of the additive Prawn Balance, there was a significant reduction in intestinal *Vibrio*.

Giant Bio Technology Co., Ltd. is a start-up company which has obtained relevant patented technology from NTOU and has developed the Herbmedotcin technology platform. Using selected high- quality food-grade raw materials, effective functional ingredients and precise nutritional formulas, 2 years ago, it launched the Prawn Balance series of shrimp functional feed additives in Taiwan. It has been proven to be the best product to replace antibiotics, increase disease resistance and maintain intestinal health and is well received by Taiwan's shrimp farming industry. In 2019, the Herbmedotcin technology was officially commercialised. A production plant compliant with ISO22000/HACCP certification was established and antibiotic replacement feed additives such as Prawn Balance/Guard and Fish Balance/Guard were produced. In this article, we describe in-depth the effect of the shrimp functional feed additive.

Pathogen challenge test

We fed white leg shrimp with a commercial diet (control group) and a diet containing the additive for 7 days in the laboratory, and then injected high concentrations of AHPND pathogenic *Vibrio* parahaemolyticus into the culture water. The survival rate of white leg shrimp after 7 days under the high risk challenge was observed.

In two independent trials, survival rates of the control groups challenged with *V. parahaemolyticus* were 28.6% and 33.3%. The survival rates of the experimental groups were 91.4% and 96.2% (Table 1). It was shown that Prawn Balance had an excellent protective ability against AHPND. More importantly, it is composed of natural ingredients, which have been verified by a third-party impartial unit and does not contain any heavy metals, antibiotics, drugs and other ingredients.

Field trials and results

The laboratory results found that this additive has a good protective effect on AHPND and there were no side effects on the growth of shrimp. Then, we conducted field trials for the entire culture cycle in commercial farms located in Ping Tung, Taiwan. This was an outdoor earthen pond with a water volume of about 3,000 tonnes, using the green water farming model.

In one culture cycle before the start of the test, the stocking density was 100 post larvae (PL)/m^2, the total harvest after 6 months of culture was 1,500kg. The survival rate was about 33%. In the field trials, the same pond and the same feed were used but the feed additive was added throughout, and the stocking density was increased to 166 PL/m^2. After the same 6-month culture period, the total yield was 3,000kg and the survival rate increased to 40%. Field trials had shown that the Prawn Balance additive did not cause any side effects on the growth of shrimp. In the same field, farming at a higher density had yielded better harvests. According to the on-site farm staff, the entire culture process was very smooth, and the amount of feeding increased steadily. Even with extreme weather such as high temperature or heavy rainfall during the culture period, no large number of mortalities was observed.

	Control run	Test run	Test site
Test Period	March -September 2019	October 2019 – April 2020	
Culture mode	Earthen pond/ green water	Earthen pond/ green water	
Water volume	3,000 tonnes	3,000 tonnes	

Table 2. Field trials in commercial farms in Ping Tung.

On-site monitoring

After completing a large-scale field trial, it was confirmed that the Prawn Balance series of products can significantly improve the survival rate, feed conversion ratio (FCR) and growth rate of shrimp. Subsequently this feed additive was officially marketed in Taiwan. However, under different culture models in different areas, whether its use can really bring protective effects was also a question often asked by customers. In response, we suggested that the *Vibrio enterica* assay described in the paper by Yen et al. can be used to test its effectiveness.

Vibrio counts in shrimp guts are more predictive of disease outbreak risk than *Vibrio* monitoring in water. The extensive use of water disinfectants to suppress *Vibrio* in water cannot completely prevent *Vibrio* from growing in the gut. In particular, the culture environment and the health of shrimp are constantly changing. From our long-term practical tests, the use of Yen's assay can often show signs of disease earlier before the outbreak of the disease. Moreover, the operation of the assay method is not particularly difficult and the method is available to be applied in the field (https://www.youtube.com/watch?v=r7F1umshpkM).

We often instruct customers to observe the changes in the amount of *Vibrio enterica* by using Yen's assay before and after using Prawn Balance. The following is a case study of one of the farmers in Taiwan. The farmer removed the intestinal tract before and after using the additive to analyse the *Vibrio* count by the Yen's assay method. (Figure 1). After using the additive, the shrimp gut was significantly thicker (Figure 2).

Concrete outdoor pond with green water (top) and an indoor pond with biofloc.

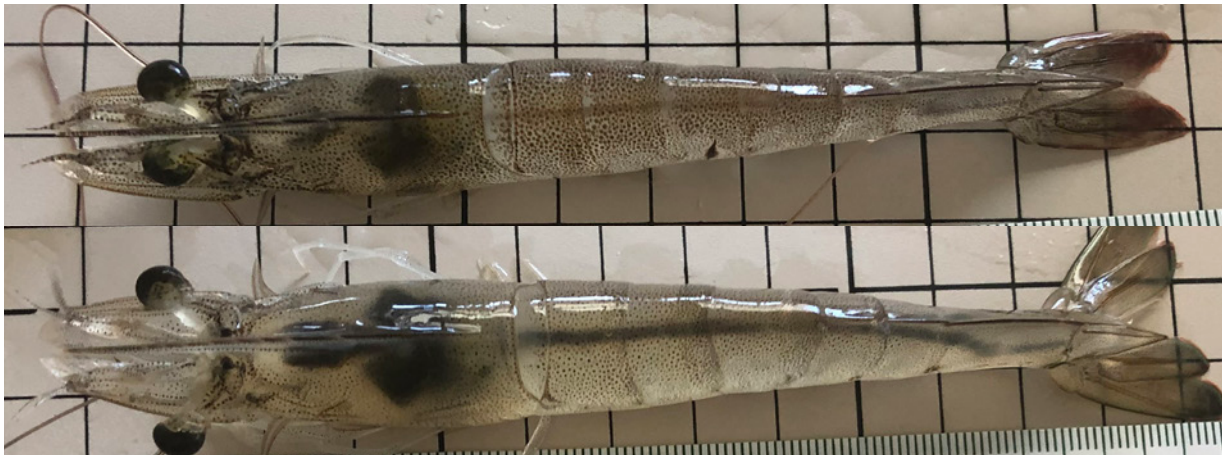


Figure 2. With dietary supplementation of the additive Prawn Balance, shrimp gut was thicker.

At present, there are more than 100 shrimp farms in Taiwan using this additive. There are farms in different regions and different culture models, which have experienced the difference the product brings to the health of shrimp.

In Table 3, we show the achievements of two farms. Although these two farms use completely different farming models, they both use Prawn Balance for intestinal health care throughout the process and Prawn Guard is used for enhanced protection every 7 days. The results confirmed that regardless of the culture model, the additive provides good results and achieves the goal of antibiotic-free farming.

	Site 1	Site 2
Location	Tai Tung/Taiwan	Ping Tung/Taiwan
Culture mode	Outdoor concrete pond with green water	Indoor concrete pond with biofloc
Shrimp density	160 PL/m^2	300 PL/m^2
FCR	1.41	1.54
Estimated survival rate	70.2%	72.3%

Table 3. Culture results with the supplementation of Prawn Balance in feeds with different culture models at two farms in Taiwan.

Conclusion

This functional feed additive has natural ingredients and does not contain antibiotics, heavy metals and pharmaceutical ingredients. After rigorous scientific evidence, including laboratory tests, field tests and market tests, it has been proven that it can greatly help shrimp survival rate, FCR and growth rate.

At present, this series of feed additives are divided into Prawn Balance for daily maintenance to maintain intestinal health and enhanced Prawn Guard for high-risk culture periods and monitored for risk through Yen's assay. With these combinations, it is possible to maintain the stability and robustness of the culture and raise shrimp without the use of antibiotics.

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Benefits of natural carotenoids from *Paracoccus carotinifaciens* on colour and immune system of Pacific white shrimp

The benefits of the carotenoid supplementation are more intense red colour than shrimp fed the control diet and in challenge tests, a reduction or delayed mortality

By Dominique Corlay and Nutt Nuntapong

Shrimp farming is facing major challenges related to diseases and product quality. Pale colour is one concern which may reduce the shrimp value in the market. Various studies have confirmed the improvement of pigment intensity by natural or synthetic carotenoid sources. Meanwhile, there is an increased demand from consumers for more natural farming practices including natural pigment for both fish and shrimp (Lerfall et al., 2016). On the other hand, the positive roles of carotenoids in shrimp have been proven in several aspects, including growth, nutrient utilisation, reproduction and immunity.

Paracoccus carotinifaciens is a unique carotenoid-rich microorganism, which contains around 40g/kg of total carotenoids, including red carotenoids such as astaxanthin, adonirubin, canthaxanthin and adonixanthin beside other forms (Figure 1). This carotenoid product has been approved since 2008 in the European Union as a feed additive in aquatic feeds for salmonids and its efficiency and added value have been well assessed in premium segments and organic aquaculture. A new study (Nuntapong et al., 2022) confirmed its benefits on colour improvement and immunological responses after pathogen challenges on Pacific white shrimp *Litopenaeus vannamei*.

Experimental design

Pacific white shrimp (*Litopenaeus vannamei*) juveniles with initial weight of 1.50±0.01g were obtained from a commercial shrimp farm in Thailand. Shrimp were fed with a control diet for 3 weeks during an acclimatisation period. At the start of the feeding trial (week 0), shrimp with an average body weight of 4.00±0.01g (40 shrimp) were stocked into fibreglass tanks. Triplicate units were randomly assigned to one diet group. Shrimp were fed on experimental diets four times daily for 30 days. Feed consumption was recorded and adjusted every day according to demand. Water quality in rearing tanks was monitored to be suitable for shrimp culture including salinity, temperature, pH, dissolved oxygen, alkalinity and ammonia nitrogen.

Four experimental isoproteinic and isolipidic diets (T1 to T4) were formulated as described in Table 1: treatment 1 (T1: C), control diet without carotenoid supplementation; treatments 2-4, diets with Panaferd-AX at 250 (T2: P250), 500 (T3: P500) and 1,250 (T4: P1250) mg/kg of diet. The carotenoid powder of *P. carotinifaciens* was added to the other ingredients and then pelleted. Results of final carotenoid contents and major zootechnical performances are shown in Tables 2 and 3.

Haemolymph and hepatopancreas samples were collected to conduct various analyses including total haematocytes count (THC), phenoloxidase (PO) activity, nitroblue tetrazolium reduction test (NBT), phagocytic activity and lysozyme activity. Antioxidant enzymes and thiobarbituric acid reactive substances (TBARs) in hepatopancreas were assessed including catalase (CAT) activity, glutathione peroxidase (GPx) activity, superoxide dismutase (SOD) activity and TBARs determined as malondialdehyde (MDA) present in the samples. Colour measurement was determined on boiled shrimp following the colour space parameters (L^* = lightness, a^* = redness, b^* = yellowness).

Challenge test

At the end of feeding trial, 60 shrimp from treatments 1-4 each were used in a challenge test study: 30 shrimp for *Vibrio parahaemolyticus* and 30 shrimp for white spot syndrome virus (WSSV). Each challenge test was performed in three replicates with ten shrimp each. Preliminary tests were performed before each challenge test began in order to find the optimal dosages (LD50) of bacterial suspension and WSSV. The causative mortality was confirmed by PCR analysis. After exposure, the mortality was recorded for 17 days.

CAROTENOIDS	%	g/kg
Astaxanthin	50.2	21.8
Adonirubin	2.4	12.9
Canthaxanthin	9.2	4.0
Adonixathin	3.8	1.6
Echinenone	3.0	1.3
β-carotene	1.6	0.7
Asteroidenone	1.5	0.6
3-Hidroxyechinenone	0.9	0.4

Figure 1. The carotenoid profile of *Paracoccus carotinifaciens*.

Ingredient	Experimental diets			
	T1 : C	T2 : P250	T3 : P500	T4 : P1250
Fishmeal	250.00	250.00	250.00	250.00
Soybean de-hulled	250.00	250.00	250.00	250.00
Wheat gluten	50.00	50.00	50.00	50.00
Wheat flour	220.00	220.00	220.00	220.00
Rice flour	116.60	116.60	116.60	116.60
Squid liver powder	50.00	50.00	50.00	50.00
Fish oil	30.00	30.00	30.00	30.00
Lecithin	10.00	10.00	10.00	10.00
Choline chloride	1.00	1.00	1.00	1.00
Vitamin and mineral premix	2.00	2.00	2.00	2.00
Inositol	0.40	0.40	0.40	0.40
DCP	10.00	10.00	10.00	10.00
Panaferd®-AX	0.00	0.25	0.50	1.25
Cellulose	10.00	9.75	9.50	8.75
Proximate compositions[2]				
Dry matter	896.66±0.67	903.76±4.41	914.44±3.94	888.29±1.76
Crude protein	383.60±4.87	390.28±6.99	387.17±5.34	387.32±6.27
Crude lipid	75.21±2.41	73.59±0.44	76.75±2.90	73.50±1.14
Crude ash	81.62±0.88	80.77±0.42	83.34±0.38	81.26±0.53

Table 1. Ingredients (g/kg diet) in formulations of the experimental diets.

Zootechnical performances

In this study, there was no evidence associating carotenoids from Panaferd-AX with growth performance as shown in Table 3. All groups had similar survival rates of around 85%, with no significant differences among the experimental groups. Final body weight (FBW), average daily growth (ADG), specific growth rate (SGR) and feed conversion ratio (FCR) also showed no significant differences (P>0.05) between the treatment groups and the control group.

Meanwhile, several studies pointed out that carotenoids may have a positive role in the intermediary metabolism, which could potentially enhance nutrient utilisation and consequently improve growth performance (Amar et al., 2001; Kalinowski et al., 2005; Wang et al., 2018; Niu et al., 2019). In some farming situations, carotenoids may indeed contribute to growth by enhancing the biological function of the hepatopancreas, a key organ for several metabolic functions, including nutrient digestion, absorption and storage.

Colour assessment

As shown in Figure 2, visual observation of the cooked whole shrimp showed clearly that shrimp fed supplemented diet with the carotenoid powder from *P. carotinifaciens* had more intense red colour than shrimp fed the control diet. In agreement with these findings, supplementation levels at 500mg/kg ((Diet T3) and 1,250mg/kg (Diet T4) gave the highest redness value *a**, above those of the control and 250mg/kg- (Diet T2) supplemented groups. According to previous studies, dietary carotenoids are mostly converted to astaxanthin and deposited in free form in the shrimp body via protein association.

Haemolymph and immune response parameters

Haemolymph parameters are reliable indicators of the health status and innate defense system of shrimp. In crustaceans, THC and PO system play key roles in the shrimp immune system. In this study as presented in Table 4, diets with the *P. carotinifaciens* powder up to 250mg/kg (Diet T2) elevated the innate immune parameters, including THC and PO activities and NBT reduction. In addition, lysozyme and phagocytic activities of shrimp were enhanced by feeding with high doses of carotenoids. This may be due to the ability of the product to increase cellular and humoral immune responses. The immune functions are directly related to the health status of shrimp.

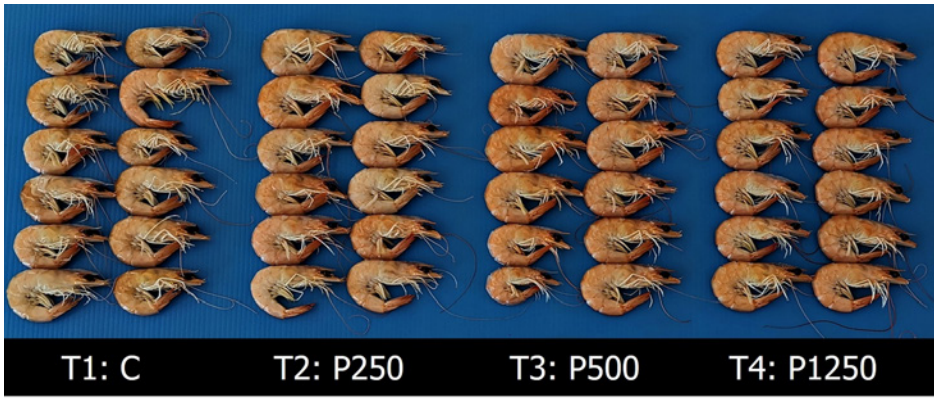

Figure 2. Colour of cooked shrimp after fed with different experimental diets for 30 days.

Oxidative stress, an imbalance between the production of reactive oxygen species (ROS) and antioxidant defenses, has been directly linked with health problems, such as cellular injury in the form of lipid peroxidation, protein oxidative damage and suppressed antioxidant enzyme activities (Niu et al., 2014). Various studies have assessed the role of dietary carotenoids, showing significantly the promotion of

Carotenoid	Panaferd®-AX	Experimental diets			
		T1 : C	T2 : P250	T3 : P500	T4 : P1250
β-Carotene	700	0.0	0.0	0.2	0.4
Echinenone	800	0.0	0.1	0.3	0.7
3-Hydroxyechinenone	200	0.0	0.0	0.0	0.1
Canthaxanthin	3,000	0.0	0.6	1.4	3.3
Adonirubin	11,600	0.0	2.6	5.4	12.8
beta-Cryptoxanthin	0.0	0.0	0.0	0.0	0.0
Astaxanthin	21,100	0.0	4.7	9.6	22.9
Asteroidenone	500	0.0	0.0	0.1	0.4
Adonixanthin	2,600	0.0	0.4	0.9	2.1
Others	200	0.0	0.0	0.0	0.1
Total carotenoids	40,600	0.0	8.5	18.0	42.9

Table 2. Carotenoid profile and concentrations (mg/kg) of the Panaferd®-AX experimental diets.

enzymatic antioxidant defense system and free-radical scavenging activities in crustaceans (Zhang et al., 2013; Wang et al., 2018).

Catalase is a major antioxidant enzyme, which is responsible for scavenging ROS and protecting tissues against damage from free radicals and phagocytosis (Chien et al., 2003). In this study, the supplemented diets had higher expression of catalase than the control diet. In addition to enzymatic antioxidant defense system, malondealdehyde (MDA) is a highly toxic substance produced via the generation of lipid peroxides, inducing oxidative stress. In this study, our results demonstrated that the MDA content in hepatopancreas of shrimp fed the supplemented diets up to 250mg/kg diet were significantly decreased from that of the control diet.

Astaxanthin has been widely used to promote the antioxidant defense system in farmed animals. The adonirubin and adonixanthin, biosynthetic intermediates from β-carotene to astaxanthin, participate to alleviate the ROS response and to reduce cell damage by oxidative stress (Maoka et al.,2013). A similar observation was reported in broiler chickens by Inoue et al. (2019) who pointed out that dietary supplementation with *P. carotinifaciens* decreased breast muscle MDA concentration under both normal and high ambient temperature conditions.

Challenge test

The survival of shrimp after the challenge with *V. parahaemolyticus* or with WSSV are shown in Figures 3 and 4, respectively. After the shrimp were challenged with *V. parahaemolyticus*, the results indicated that shrimp fed diets with carotenoid supplementation had higher survival rates compared to the control, when the trial was terminated (17 days). The survival rate of the control was 15% (T1: C) whereas it ranged within 30-40% in the treatment groups (T2: P250-T4: P1250). For shrimp challenged with WSSV, mortality started from day 4 onwards (control group, T1: C) and shrimp in all replications had died by day 5, while carotenoid supplemented shrimp had significant delayed mortality rates.

The higher pathogen resistance of the supplemented fed shrimp was directly linked to its health status and immune responses (Lin et al., 2013). In the current study, the improved resistance of Pacific white shrimp to a challenge with *V. parahaemolyticus* may be partially attributed to the stimulation of non-specific immunity by promoting THC, PO activity, phagocytosis and antioxidant defense system of shrimp. During the challenge test against WSSV, the shrimp fed the supplemented diets exhibited higher resistance to WSSV infection than the control group, in line with the results reported by Wang et al. (2015).

Parameter	Experimental diets			
	T1 : C	T2 : P250	T3 : P500	T4 : P1250
IBW[1] (g/shrimp)	4.00±0.01[a]	4.00±0.00[a]	4.00±0.01[a]	4.00±0.01[a]
FBW[2] (g/shrimp)	8.22±0.29[a]	8.35±0.23[a]	8.34±0.23[a]	8.07±0.52[a]
ADG[3] (g/shrimp/day)	0.14±0.01[a]	0.14±0.01[a]	0.14±0.01[a]	0.14±0.02[a]
SGR[4] (%/ day)	2.40±0.12[a]	2.45±0.09[a]	2.45±0.09[a]	2.34±0.21[a]
FCR[5]	1.20±0.04[a]	1.17±0.19[a]	1.02±0.01[a]	1.16±0.12[a]
SR[6] (%)	81.67±8.04[a]	83.33±11.27[a]	91.67±1.44[a]	89.17±3.82[a]

Values are given as mean (n = 3) ± standard deviation. Mean values in the same row with different letters are significantly different ($P < 0.05$)
[1]IBW: Initial body weight (g/shrimp)
[2]FBW: Final body weight (g/shrimp) at days 30
[3]ADG: Average daily gain (g/shrimp/day)
[4]SGR: Specific growth ratio (%/day)
[5]FCR: Feed conversion ratio
[6]SR: Survival rate (%)

Table 3. Growth parameters and survival rates of Pacific white shrimp fed with different experimental diets for 30 days.

Parameter	Experimental diets			
	T1 : C	T2 : P250	T3 : P500	T4 : P1250
THC[1] (× 10^8 cells/mL)	2.58±0.45[a]	3.35±0.43[b]	3.28±0.69[b]	3.60±0.62[b]
NBT reduction[2] (OD 630)	0.49±0.11[a]	0.59±0.09[b]	0.60±0.11[b]	0.61±0.10[b]
PO activity[3] (U/mg protein)	290.38±96.35[a]	501.46±126.74[b]	451.43±113.31[b]	499.40±90.97[b]
Lysozyme activity (U/mg protein)	13.19±3.86[a]	16.53±4.74[a]	17.27±4.99[a]	22.80±5.53[b]
Phagocytic activity[4] (%)	24.19±1.44[a]	24.60±2.24[a]	31.00±3.23[b]	40.90±6.49[c]

Values are given as mean (n = 12 shrimps) ± standard deviation. Mean values in the same row with different letters are significantly different (P < 0.05)
[1] THC: Total haemocyte counts (× 10^8 cells/mL)
[2] NBT reduction: Nitroblue tetrazolium (NBT) reduction (OD 630)
[3] PO activity: Phenoloxidase activities (U/mg protein)
[4] Phagocytic activity mean (n = 3)

Table 4. Haemolymph parameters of Pacific white shrimp fed with different experimental diets for 30 days

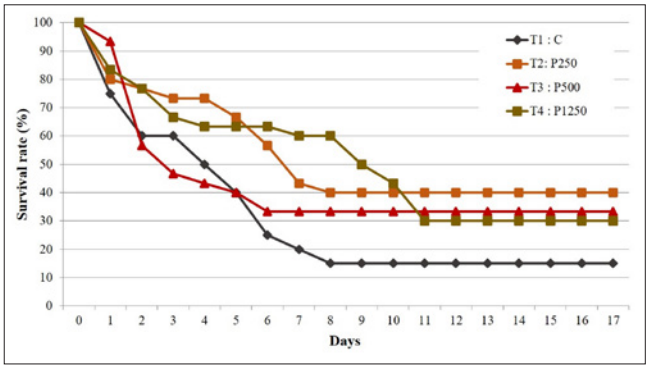

Figure 3. Survival (%) of shrimp from each dietary treatment after challenged with *Vibrio parahaemolyticus* for 17 days.

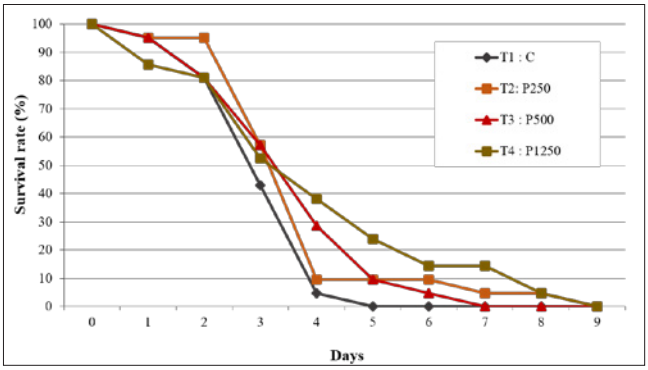

Figure 4. Survival (%) of shrimp from each dietary treatment after challenged with white spot syndrome virus (WSSV) for 9 days.

Conclusion

This new study confirmed that the carotenoid supplementation from *P. carotinifaciens* in shrimp feed enhanced the pigmentation of Pacific white shrimp, a key quality parameter of consumers in most markets. These carotenoids also stimulated their immune system, disease and stress resistance. The supplementation at as low as 250mg/kg diet achieved good results for several immune parameters (THC, NBT and PO) and stress responses (CAT and TBARs). During acute pathogen challenges, the natural carotenoid had also proven it could sustain the immune shrimp system by reducing or delaying mortality. With its unique carotenoid-wide profile, the natural carotenoids from *P. carotinifaciens* represent an efficient natural nutritional tool in most shrimp production systems.

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Nuntapong, N., Phromkunthong, W., Suanyuk, N., Corlay, D. 2022. Natural pigment from Paracoccus carotinifaciens (Panaferd®-AX) enhanced colour and immune system of Pacific white shrimp (*Litopenaeus vannamei*). Aquaculture Research. doi.org/10.1111/are.16061

All other references are available upon request

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Risk mitigation and investments in Asia's aquafeed sector

Views from five industry players at the TARS 2022 industry dialogue

The five industry players at the Industry Dialogue during TARS 2022 were, from left, Carlos Diaz, Aaron McNevin, Piers Lakin, Michael Sweeney and Benedict Tan. Ronnie Tan (right) moderated.

There is no doubt that Asia's aquafeed industry is facing challenging times, from the pandemic-led high freight costs and supply chain disruptions since 2020 to the war in Ukraine with rises in raw material and high energy costs. Inflationary pressures affect all players along the supply chain. During TARS 2022 Aquafeeds: A New Equilibrium, the industry dialogue featured five industry players discussing actions for risk mitigation from increasing ingredient prices; attracting investments and learning from the salmon industry, among others. These were some issues that were highlighted by Ronnie Tan, Aquaculture Lead at US Grains Council, Malaysia. Below are some excerpts from this one-hour dialogue.

"The commercial aquaculture industry in Asia has reached almost half a decade and the regeneration of an industry depends largely on two processes. First, a succession plan, and second, is investments. Investments will be the focus of this dialogue," said Tan. The panel comprised the following, each an expert in their field.

Carlos Diaz (CD), CEO at the BioMar Group in Denmark is a company veteran of over 20 years who led the transformational change at the company to be the leader in sustainable aquaculture feeds through innovations including the adoption of circular and restorative raw ingredients.

Benedict Tan (BT) is Program Manager at Hatch Blue, Singapore and has worked with more than 90 startups to help validate their ideas and technology, understand key market insights and pitch for investment.

Michael Sweeney (MS) is Partner at Bluegrass Partners, Hong Kong and has contributed over 12 years on the agribusiness sector in emerging markets. The company has a unique approach to the emerging market agribusiness linking industry players, financial capital and operational expertise within the UN Sustainability framework.

Piers Lakin (PL) is Senior Associate of Investments and heads shrimp investments at Ocean 14 Capital, UK. He brings with him 8 years of experience in sustainable finance and private equity.

Aaron McNevin (AM), Global Network Lead, Aquaculture, World Wildlife Fund, USA has helped to launch an alternative ingredients consortium to allow pooling of resources to make leaps instead of steps in impact reduction.

Risk mitigation

How do aquaculture feed companies derisk themselves?

CD: There are several problems to handle, including interruptions of supply chains. We innovate with raw materials, to depend on less raw materials, and to have a bigger basket. We move from a transactional relationship with suppliers toward more strategic partnerships to secure the raw materials.

We work together and forge strategic partnerships with customers to help them understand how they can overcome financial risks. As a global feed supplier, being present in most of the aquaculture hubs around the world and having your eggs in different baskets is a good way of derisking. It is very seldom that all of them go down at the same time. Usually, there are ups and downs in different geographical regions.

Transparency in food safety is very important. In the past, we have seen some food safety or transparency risks or scandals but much less today. The social governance part of ESG is a reputation issue. Working with communities is becoming more important to investors around the world.

MS: To derisk, efficiency and scale are what matters in feed. There is a constant battle to continually innovate.

From an investor's perspective, most investments have gone towards the salmon industry. I think what has pushed the other species aside is its fragmented nature. Particularly true in Asia - with different species and regions and climatic zones; how can we create that same story in this region and attract that institutional investment?

Any advice on managing cash flow with interest rates rising and inflation?

CD: We have seen a huge increase in price of raw materials and inflation, driven first by Covid, then by the war in Ukraine. However, feed is not a black box; the only way to manage the inflation at different levels in different countries is by working in partnerships with customers to understand our cost structure and our transparency. Eighty percent of our cost is raw material costs and the only way to address this is by innovating with R&D and finding new alternatives to be more efficient and more sustainable.

On risk mitigation, *"We work together and forge strategic partnerships with customers to help them understand how they can overcome financial risks." – Carlos Diaz*

MS: I agree that to manage the supply chain, you really must be the most efficient producer, managing costs, overheads, procurement and supply chains. But we have to recognise that with the inflationary environment today, there is no way that you can manage your overheads and eat up the current costs of inflation. To pass that on to your customers, you have to be closer to your customers and show the value of ingredients in the feed and how it accrues to them.

One of the dangers is the race to the bottom - to get the cheapest feed on the market. For many ingredients, the value does not accrue to a feed miller but to the feed user. It is communicating the value of the ingredients and of the feed, to each customer because ultimately, you want them to pay more for a product which can deliver better results for them. This is going back to partnering with the customers and suppliers.

Investing in Asia's aquafeed industry

What are sweet spots or specific areas that attract investments within the aquafeed industry?

BT: HATCH looks at different ingredients, mainly in the protein and omega-3 oils segments and in terms of scale and competitiveness with other products in the market. The sweet spot that we really look for is the ability to scale. We also look for more than 70% protein content and prices at scale at less than USD1,500/tonne and for omega-3 oils, we are looking for less than USD2,500/tonne with more than 15% EPA or DHA content. This may change in a post-Covid world. It is a

question of scale and whether it has been tested with the major species. Primarily, we are a venture investor and we do need to deliver those returns to our limited partners (LP).

MS: Recently, I have seen investments in three areas. One is fish with a lifecycle of feeds at different stages - hatchery, growth and finisher. There is the alternative ingredients space, whether its single cell, insect meal or also some of the new innovations in taking a waste product and turning it into feed.

There is the integration part, where there is a split between private investors and the institutional side. Many companies in Asia are making investments in feed factories in different regions and focusing on different species. Unfortunately, institutional investors are not getting involved as aquaculture is seen as not sexy enough to draw attention at conferences.

Several banks invest in the salmon industry, but how many of those international banks are investing, for example, in the Vietnamese shrimp industry? I really think that they need to be doing that more, particularly from a food security point of view, but also to help industry improve, create efficiencies and increase the value proposition within the region. Of course, the environmental and social benefits will follow.

PL: Our first investment is in SyAqua, the shrimp genetics and specialty nutrition business. We have developed a strategy largely around this investment: focusing on genetics, specialty nutrition, data and automation and environmental services. These four pillars are very complementary.

We target both the hatchery and the farm segments and go for high value, high margins and therefore high impact nutrition products. Within this strategy, this is a sweet spot for us. Broadly, our scope of investment is on these four criteria, rather than on an aspect of the industry in particular.

We are interested in the right team. The company has strong access to the industry, is very knowledgeable and has a deep knowledge of the industry and is very good on the execution side. This is where we see value being created in the industry.

Are there examples of a dream company to invest in?

PL: My example would be SyAqua. The proof of execution and traction that excites us is a company with a very strong team with a long background in the industry with access across the industry, both on the supply side and the demand side, knowledgeable on their products and with a lot of deep ingrained IP and R&D. Additionally, it has a decent market share of the industry.

What are the characteristics of companies to attract investors?

BT: Teamwise, they need to have realistic expectations in terms of what the valuations will look like, what their road to commercialisation will be, especially as feed, feed ingredient or feed additive producers. They need to have credible technology proven to a certain extent; not specifically proven in the aquaculture market. Besides the processing technologies for plant proteins, they need to be more competitive in the trials with products on the market.

There is a Montana company run by two cowboys in their 70s, making aquaculture sexy. They have developed a competitive barley protein product. Hatch wants to be that entry point for other capital to understand aquaculture better, educate other investors, and maybe some LPs will come on board. This was a good case study for us and for aquaculture in general as USD80 - 100 million have been invested in a European facility to scale up.

This is why Hatch came with at least the business accelerator approach when we are looking for these talents. For those innovators sitting in a research facility or a micro plant in Montana or Hawaii, we want to bring the aquaculture industry to them, to make the aquaculture industry less insular.

What about some mismatch for investments?

PL: Until recently, valuation has been a sticky point for us, particularly with slightly younger companies. Over the last couple of years, we have seen a lot of very high valuation expectations for the stage of the company. From our perspective, that can put a business on a very risky footing. It can put them in an unrealistic growth trajectory and end up going after the wrong things as they are desperately trying to keep the valuation premium at bay.

There has been a big shift in attitude in the last couple of months. It will be more difficult for companies but will be healthier overall in terms of growth at a more sustainable level, with more realistic trajectories and less failures.

For early stage companies, there is a need to use proper trial data and prove the market fit for the product as well as to be realistic on what is achievable in a certain time frame. It is how fast you can realistically penetrate the market and what type of market share you can grab. The industry is very competitive.

In perceptions on investing in Asia, *"Some of the big institutional players are definitely showing interest in investing in the region and in aquaculture." – Piers Lakin*

Are there any other components of the aquafeed industry of interest for investment as well?

MS: As we know, 80% is global commodity. However, what is highly valuable and feed companies need to be investing in it, is a kind of a holistic view of what they are delivering to their customers. We know that Asia is very fragmented with small, mid-size and large players. What are the technical services and education, sustainability metrics and traceability are we providing for our customers? All these are qualitative.

I think if someone wants to build just a factory and says that 'we are going to produce the lowest cost feed', it is not going to be as interesting to investors. So you have to really approach it from a more holistic point of view. How are you value adding to your customers and helping to move the industry along? Today, we have to really improve the quality of the investment.

BT: I am looking at feed adjacent technologies such as biomass sensing - knowing what is in the pond real time instead of sampling with a net. Realistic farm management is required. There is a startup, serving maybe 0.25% of the Southeast Asian market, which is over 14,000 farmers and approaching the fragmented market in a different way. We are really counting on these tech companies, in terms of a growth trajectory. It requires a lot of hard work on the ground to attract farmers and to win them over. There is a question of data ownership; should the farmers own the data or the feed companies?

What are the perceptions on investing in Asia?

MS: A year ago, we did not think about war, but now it is at the forefront of many investors' minds. I do think that Southeast Asia-Vietnam, Thailand, Philippines and Indonesia is really going to benefit, particularly in the aquaculture space. I see a lot of promise for this region and there is going to be a lot more strategic investments here. This will hopefully bring institutional investors, FDIs, and some of the banks as well.

PL: Over the last few years people are becoming comfortable with Southeast Asia. Big institutional players are definitely showing interest in investing in the region and in aquaculture particularly with interest in accessing sustainable financial deal flow in the region.

On the inflationary environment today, *"To pass that on to your customers, you have to get closer to your customers and show the value of ingredients in the feed and how it accrues to them,"* *- Michael Sweeney*

AM: The World Bank's getting back into investing in aquaculture and is a partner with WWF on the Aqua Business Advisory Platform. The Asian Development Bank may follow and get back to investing in aquaculture.

Why is investing in Asia not as interesting as investing in salmon in Europe or shrimp in Ecuador?

CD: There is fantastic potential in Asia. The reason why Asia is seen as not as interesting for investors is that some of the international companies have not been very successful when they tried to apply exactly what they do in salmon or in Norway. Investors just need to find the way to do it here in Southeast Asia and India.

ESG and Sustainability

Does sustainability come in second since the discussion has been on return on investment first. How important is ESG and sustainability?

AM: Back in 2014, we had reports of forced labour in Thailand brought in by the retail and the food service sectors. It brought all the retailers and the food service sectors to look at this region and the challenges are some of the disconnects from the feed and processing of aquaculture products sectors. Today, more retailers are asking about feed because a pangasius product, or a shrimp product has many ingredients going into it and packaged with risks and liabilities in farming and then passed on to the retail sector.

Back in 2014, it could be that feedmills were certified and indicated sustainable sourced proteins which was not true. Again, it is this dichotomy, with salmon and the majority of aquaculture, which is 80% in Asia. My advice would be to start with an expected level of transparency. Obviously, the business needs to make money and that money empowers you to be able to do better things. Therefore, sustainability comes in second place, because you need the money to do things.

CD: It is not a coincidence that companies that focus on social governance, ESG, and those that have a purpose usually are the most profitable ones. These are usually the ones who also already care about ESG. Our team spends time discussing with retailers and NGOs to develop sustainable concepts. It is to have sustainability and to be responsible. Hopefully, we can commercialise and sell

this industry better as the young generation care about this. Sustainability should not be seen as a burden but a big opportunity to commercialise it and tell the story of aquaculture as the best way of producing protein in a more sustainable way.

Technological advancements

Are there lessons to be learnt from the salmon feed industry or other animal feed production sectors?

AM: I see a dichotomy between salmon and Asian production of aquaculture. In the former, there are a lot of advances, tremendous amount of innovation as well as transparent reporting, which, unfortunately, we do not see coming out of Asia. There is the notion that products from Southeast Asia, such as shrimp, as cheap. So where is the money to reinvest, such as into integrity programs? BioMar is part of the Global Salmon Initiative (GSI) and this is an example of the effort around image of a global product. If there is a lesson to be learnt from the salmon industry, it is that there are certain benefits of consolidation.

Coming soon to Asia Pacific will be more requests for more information regarding feed. Customs and Border Protection is asking processors about the feed supply chain. I think that the level of transparency and reporting in the salmon industry is one of the big lessons to be learnt in the Asia Pacific region.

On ESG and sustainability *"I think that the level of transparency and reporting in the salmon industry is one of the big lessons to be learnt in the Asia Pacific region." - Aaron McNevin*

CD: Asia has many species, and it is different to operate in China, Vietnam, Indonesia, Thailand or India. We can use the technical part of the salmon model in feed production for Asia but only in terms of digestibility, raw materials, amino acids, and sustainability to apply to different species.

In working with communities, Asia can work better with the communities faster than what the salmon industry has done. Ecuador has the Sustainable Shrimp Partnership (SSP), which is also a competitive edge and doing things more responsibly. These are some initiatives that could be good for Asia as a whole or for a single country.

With regards to consolidation, here in Asia, there are many small companies which do not have the scale. Small producers sometimes are squeezed by just producing. Consolidation has happened in the salmon industry and in the shrimp industry. Barramundi, kingfish and perhaps cobia have the fundamentals to become the future salmon. We cannot expect salmon production to grow much more.

PL: One of the issues with the industry is that most people are very cagey about their process and in particular their data. People continue to make decisions based on historical know-how rather than data driven insights. The more the industry opens ups and shares performance data, the more they can build that feedback loop across different companies through a more collaborative model. Sharing some of the feedback from the performance of the technology will undoubtedly improve technology and efficiency.

Integration

The reason why salmon in Europe, sea bass and sea bream in the Mediterranean and shrimp in Ecuador has grown so well is because many are integrated companies. Do you think integration is the future?

BT: I think integration is the way to go. For example, a farm in Vietnam can mitigate some of the costs with its own feed mill. They can manage and reduce the costs of raw materials and are able incorporate some of the new alternative feed ingredients to replace some of the fish meal. They can secure a stable supply of fry of good genetic sources.

On investing in Asia's aquafeed industry, *"The sweet spot that we really look for is the ability to scale." – Benedict Tan.*

MS: Integration can be ideal but is probably only available to companies with the capital to invest. Smaller and maybe medium-sized companies need to look at different models such as partnership models and maybe contract growers. They can bring some of the smaller farmers in and share the genetics, share the feed and find different ways to bring the players closer together.

PL: I think integration requires consolidation. We have not seen this done at the speed in the shrimp industry as compared to other protein production industries. I do not think that integration is necessary. It is possible to build stability and efficiency of production through other methods.

CD: BioMar does not believe in integration with farming or the opposite We believe in integration in the processing and the commercial part. I fully agree that consolidation is important. There are many who think that producing feed is a fantastic idea. However, feed production is capital intensive. A company can make a feed and replace fish meal, which is not necessarily the best idea in the world. To know how to do this responsibly and have the trials and conduct R&D, your company needs to be quite big. The best salmon farmers in the world, or the most efficient ones, are those who are not completely directly integrated.

AM: I think one of the challenges with vertical integration is that it is a kind of corporate bureaucracy. There are layers of bureaucracy and balancing acts and does stifle some of the innovation.

Adapt to pivot in Asian aquaculture

Managing volatility and challenges in Asia's aquafeed industry and look at Ecuador's shrimp industry

Dr Benedict Standen, Head Aqua Marketing Global, (left), led the panel discussions with speakers, from second left, Rodrigo Martinez, Dominique Bureau and Robert Redman. He said, "It is astonishing that this is the 27 year for this conference, achieved with the collaboration of the aquafeed and aquaculture industry."

DSM Animal Nutrition Asia Pacific organised its 27th DSM Aqua Conference as an in-person meeting. The theme was "Adapt to Pivot" and was held on November 23 in Bangkok, Thailand.

In his introduction to the conference theme, Achyuth Iyengar, Senior Director, Performance Solutions, DSM Nutritional Products Asia Pacific asked the audience to reflect on challenges facing the aquaculture industry - high prices for soybean meal (SBM) and high omega-3 oil prices as demand from petfood and human nutraceutical competes with aquafeed players; land and water use; sustainability; and climate change. "Today, we are confronted with these and other challenges. Together we adapt to pivot and to unlock value through data and evaluate hidden risks. Most importantly this conference is about learning together and growing together with our customers and partners over the years."

The program had six presentations from industry experts from around the world discussing some of the hot topics faced by the industry: how to manage feed ingredients volatility, outlook on aquafeeds and getting value from nutrients in formulations; managing risk from mycotoxins in aquaculture; assessing novel nutritional and functional ingredients for aquafeeds; unlocking the value of unavailable nutrients in common feed ingredients through data-driven techniques and trends in shrimp farming in Ecuador.

Volatility in feed ingredients and managing risks

In the presentation "Using Financial Tools to Navigate Volatile Markets," **Rodrigo Martínez**, StoneX Financial Inc, USA, gave an extensive overview of volatility and how it affects the feed business and why do a risk management. He discussed risk assessment, risk management policy and touched on futures and options as well. The latter included strategies and building a purchasing portfolio.

The image of a roller coaster emerged during the discussion on volatility, with mentions on price changes over specific time periods. His message was, "It is important to learn to handle volatility to control risk and being proactive instead of reactive. SBM prices were stable and low prior to the pandemic but there was already high volatility over 2012-2014." With regards to risk assessment, Martínez showed some calculations to assign a dollar value on risk to the business such as by assuming a consumption of 12,000 tonnes per year of SBM and also to put a budget to help cover that risk.

Implied volatility is a forward projection of what the market is expecting in future. The amount of risk can be factored into the market and can be obtained through the Black-Sholes option pricing model. Martínez showed a chart on historical and implied volatility for KC wheat from 2012 to 2022 and reiterated that this is a measure of expected risk/market uncertainty into the future. Before the Covid pandemic started, the volatility was 15% at a 68% probability. In 2022, this was more than 50% volatility at a 68% probability. The smaller the number the lower the expected price variation.

A company needs to establish a risk management policy. "A risk management policy allows a company to keep a forward view of the market, to be proactive instead of being reactive and have the framework to allow a risk/purchasing manager to operate efficiently. It is also to stay within budget, obtain cost stability in time and to stay competitive in the local market," said Martínez. Some strategies include having a risk management committee.

This presentation also discussed having forth-coming contracts which are legally binding contracts to make or take delivery of a specific commodity at a future date. This can be assumed to be similar to insurance policies. The idea of hedging portfolio was also discussed.

Martínez concluded that, "We need to be clear of the objective we would like to reach. In a risk management program, it is important to limit the effects of emotions from our decision-making process and we need to be consistent in applying the decisions we take."

Department of Fisheries, Thailand's Dr Juadee Pongmaneerat (left) with from second left, Achyuth Iyengar, Bunluesak Sorajjakit, Thai Union FeedMills and Mongkol Kaewsutas, General Manager, DSM Thailand.

Benedict Standen with speakers, Yahira Piedrahita, Rui Alexandre Gonçalves and Dominique Bureau. Gonçalves presented on mycotoxins in aquaculture.

Where next for aquafeeds?

Robert Redman, Consultant Asia Pacific, Veramaris, began his presentation with an overview of the expected growth in aquaculture as 90% of global fisheries is at the edge of collapse. Supply of shrimp and marine fish from aquaculture is expected to increase and this translates to increased production of aquafeeds (see figure). "This rise in aquafeed production puts a strain on the already limited supply of marine ingredients and oils. Aquafeeds is the largest user of fish oil but growth in demand for fish oil is being led by petfood and human nutrition, sectors which are less price sensitive than for aquafeed production. Cost inflation for feed grade fish oil has been rising; South American fish oil has risen by 2.4 times and twice for North Atlantic fish oil."

The need for omega-3 oils has been increasing. In 2015, Veramaris, a DSM and Evonik joint venture saw this need to produce a GMO-free EPA and DHA omega-3 oil from marine microalgae to fill the gap between supply and demand for marine oils. "Dietary essential fatty acids (mainly EPA, DHA) have roles in supporting better fish health, survival and farm productivity. When the salmon aquaculture industry reduced fish oil levels in the diets billions of dollars were lost through mortalities. This industry has reverted to increasing the omega-3 levels by 30 to 50% in diets to counter this," said Redman.

Requirements for EPA/DHA

Veramaris has guidelines on total EPA and DHA requirements for the marine shrimp and Asian seabass which change across the life cycle. Ratios of n-3:n-6 fatty acids are also important. "There may not be a large difference between requirements for 1g to 10g shrimp, but the important part is how to make the animal more robust i.e. make the challenges in farming less challenging. Across life stages of the seabass, the changes are more significant."

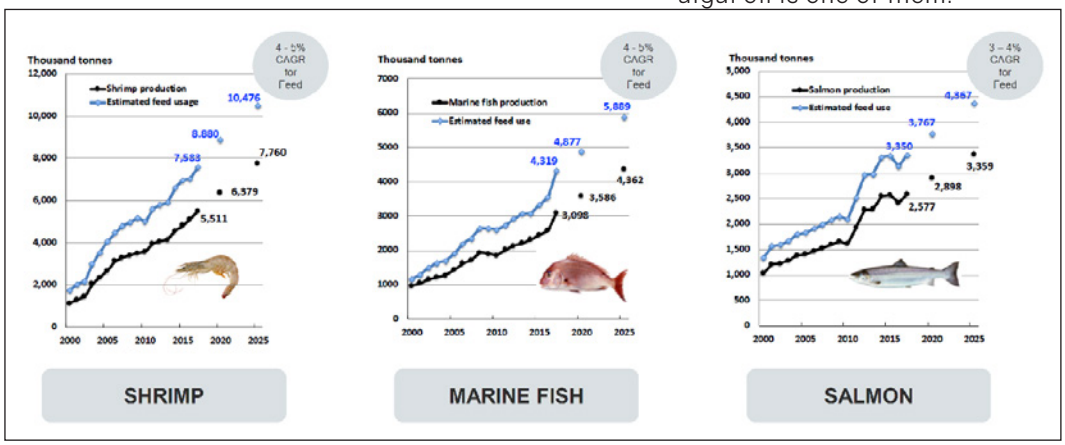
In terms of sources of fish oils, 48% are from by-products (tuna, salmon and pangasius oils) versus 52% from whole fish. Questions have been raised on the sources of materials, the variability and issues of traceability.

Consumer demands

At the other end of the chain, consumers are becoming more focussed on what they are eating and where the fish comes from and how sustainable is the product. "We see supermarkets pushing these demands back to the farmers. This means sustainable ingredients which meet omega-3 requirements for the fish and for human nutrition. A key focus for Tesco, the UK supermarket chain, is sustainability in aquaculture which amongst others, requires the increased use of sustainable oil and meals as well as alternative ingredients. Some 60-70% of the consumer's decision depends on what is the information on the packages."

Redman concluded that changes for aquafeed include continued decoupling from marine ingredients, using less as more demand increases from other sectors. There is increased focus on sustainability and nutritional metrics and already happening is the use of oils and meal from by-products. The focus is also on getting nutritional value of aquaculture products. "There is supply chain complexity with multiple sources, increased compliance and traceability."

Finally, Redman asked, "Is the aquafeed industry going to be the least cost supplier or be a partner with farmers in getting a premium price on sustainable products? To get here, we will need an alternative source of oil and algal oil is one of them."



DSM Animal Nutrition and Health Asian team is larger with the acquisition of BIOMIN in 2020.

The sustainability focus in Ecuador's shrimp industry

Ecuador is the world's leading exporter of shrimp at 848,000 tonnes valued at USD5.32 billion in 2021. In the last 10 years, Ecuador has been doubling its production every 2.5 years and in her presentation on "Principles, practices and trends of shrimp farming in Ecuador" **Yahira Piedrahita**, Executive Director at the National Chamber of Aquaculture (CNA) expects production to reach 2 million tonnes by 2027. CNA is a non-profit association with members from all along the value chain.

The industry comprises 20 broodstock facilities, 200 hatcheries and 3,800 farms. There are 80 processing plants with 46 of them with EU export permits. Supporting the industry are 18 feedmills.

"The industry has gone through changes since the early days in the 1970-1980s," said Piedrahita.

"The recovery from white spot syndrome virus (WSSV) outbreaks which started in 2000 was at the end of 2006. We sustain growth from then on and use only tolerant/resistant broodstock from local genetic programs with no imports. We now have moved to semi-intensive culture systems stocking 15-25PL/m^2 with 2-3 phases. Functional feeds are common and farms now use automatic feeders and acoustic sensors to optimise feed use and artificial intelligence to estimate size and health of shrimp."

Since 2006, the average pond size has changed from 15-30ha during the 1970-1980s to 1-5ha but biosecurity remains a challenge. Currently, the farming area is 218,352ha. "The increase in total area over the last 21 years was less than a fifth. Industry became more productive and we went from 215kg/ha/year to 3.9 tonnes/ha/year," added Piedrahita.

SSP and action to drive a change

In 2017, a farmer-led initiative - the Sustainable Shrimp Partnership (SSP), which places importance on sustainability and consumer safety was established. Piedrahita said, "There are now 12,000ha of farms in this program which is helping raise the quality of their product leading to certification. Farmers cannot use antibiotics in all the cycles even in the hatcheries. SSP conducts regular testing. Water released from the farms must be equal in quality to in-coming water. There is a QR code which provides information on the product. Under the program, farmers must report on all inputs and in turn inputs have to be registered, including all feeds. Because of this, block chain traceability is not complicated for us."

Since 2006, when the National Control Plan was enforced, Ecuador has no rejections due to antibiotic residues. "Local regulations are in line with requirements of its main markets, EU, USA and China. SSP certified farms can easily pass all the sampling tests and audit on antibiotics because they are already familiar to culture shrimp without using antibiotics." added Piedrahita. Building consumer trust is important for CNA which continues to build up transparency with authorities in its export markets. Further to this, Piedrahita said that CNA is also working with FDA on consumer food safety for its products in the US. It is also working with WWF-Ecuador to halt habitat conversion for shrimp farming across the nation.

The leading market for Ecuador's shrimp is China at 60% of exports, estimated at 885,000 tonnes in 2022. This is still below the 70% of exports achieved in 2017, prior to the pandemic. The production increase over the last 10 years has been in response to the increase in demand from China. Today, a concern is the market situation with the lower selling prices, sometimes at breakeven point.

Moving forward, Piedrahita listed some steps, "Together with the target on environmental sustainability, there is need for a strategy on climate change. In farming, there is dependence on diesel and electrification of operations is needed. We must take care of diseases as we use pathogen exposed stocks. We must also strengthen biosecurity measures in hatcheries and farms to prevent disease outbreaks."

Unlocking the value of unavailable nutrients in common feed ingredients

Digestibility of protein is known to vary across different ingredients. It is high at more than 85% for many standard ingredients such as high-quality soybean meal (SBM), fishmeal and spray dried blood products. Many other ingredients, such as feather meal and rice bran have lower (< 85%) and/or more highly digestibility of protein.

Dr Dominique Bureau, University of Guelph, Canada, said that there is evidence suggesting that a significant proportion of the nutrients contained in ingredients imported into Southeast Asia, despite at great costs, are indigestible or not bioavailable to fish and shrimp.

"The question is also, how much of these nutrients are indigestible or not and what are the costs, in terms of economics and environmental impact. Are there any cost-effective solutions available?"

Digestibility data and ingredient quality

In a recent trial, the apparent digestibility (ADC) of protein, energy and amino acids of seven commercial ingredients showed highly variable results for ADC of protein, from 69% up to 95%. Bureau explained, "Processing of ingredients determines digestibility of protein. The purity of the ingredient does not determine their digestibility. Three out of seven ingredients had less than 80% of their protein content indigestible, which means that for every tonne protein purchased, there will be 200kg unavailable and that is a very significant amount."

There are three possible reasons for the poor ADC of protein of ingredients. Bureau believes that the main reason is thermal damage - overheating or excessive heat treatment. The chemical reactions associated with thermal damage are being investigated by his research group. The second reason is nutritional interactions, due to the effects of anti nutritional factors or nutrient interacting together. Saturated acids will negatively impact the digestibility of other fatty acids. The third reason is the difference between species with regards to the ability to digest nutrients. "But the biggest difference is for phosphorus and other minerals and not so much for proteins and fats."

Digestibility does not always imply bioavailability

In some instances, digestibility does not accurately show bioavailability of amino acids. In trials with the rainbow trout, diets deficient in arginine but supplemented with either highly digestible feather meal (a good source of arginine) or synthetic arginine showed that the former diet was not effective.

Bureau said, "Digestibility is a measure of the disappearance of the nutrient and not of its bioavailability. Digestibility trials must always be backed up by a measure of growth."

The explanation was linked to thermal damage of the ingredient. At Guelph, the solution was to further process the ingredient using a cost-effective technique. A chemical treatment of a commercial feather meal with a combination of sodium sulphide and protease significantly improved the protein and amino acids digestibility by 8-22 percentage points.

Estimating the economic value of ingredients

There are two methods to do this: shadow pricing in a feed formulation program but this is very scenario specific and depends on the conditions imposed; and the other is the broad and general evaluation which is used in AquaOp Feed software developed by Wittaya Aqua. The company has developed 18 country specific databases each with approximately 40-60 ingredients. Data is regularly updated with the current market price of ingredients. A summary of economic evaluation in four countries was presented. The range of prices of vegetable protein in October was USD1.70 -2.37/kg whereas that for starch it was relatively constant at USD0.29-0.35/kg.

Bureau also showed how the pretreated feather meal at 81% CP moved up the ladder in terms of economic value compared with regular feather meal. He encouraged industry to explore such methods to make the nutrient content of ingredients more available.

Feedmillers in Asia have the option of using local fishmeal in feed formulations. However, they need to first determine how cost effective are these sources of local fishmeal. A simulation using digestibility data showed the impact of digestibility where a 30% reduction in protein ADC of fishmeal resulted in an increased feed cost of USD43/tonne or about USD1.5/percentage point of protein digestibility. Bureau recommended to invest efforts in characterising the ingredient.

Unlocking value of ingredients

There are solutions available to improve digestibility with supplementation of enzymes and emulsifying agents. Some scenarios using simple shadow exercises showed the impact of protease and phytase on ingredient cost of feed. When protease is added into the feed to improve digestibility by 3%, the saving is USD2.89/percentage point of ADC for a tilapia diet and USD3.49 percentage point of ADC in a marine shrimp diet. An improved digestibility model developed by Wittaya Aqua showed how phytase in the feed for Asian seabass will significantly increase phosphorus ADC and can help reduce feed cost by about USD3/kg. "In this case, it is not just the cost savings of feeds but also the implications on the environment and image of the final product."

The take home message is that solutions exist to improve the digestibility and bioavailability of nutrients but these need to be carefully evaluated using real life scenarios.

Next issue: More on this DSM conference with reports on mycotoxins in aquaculture, by Dr Rui A Gonçalves and novel nutritional and functional ingredients for aquafeeds, by Dr Viviane Verlhac Trichet.

The story of hybrid Tilapia X Jade Perch in Singapore

A by chance hybridisation is now in generation 4 and is moving towards commercialisation

By Joe Ng

There are variants in colour - orange, black and silver in the 4th generation of the tilapia X jade perch hybrid achieved in 2022 at Century Aquaculture, Singapore.

In land scarce Singapore, it is imperative to develop or source new species of fish that are suitable for our local industry players and where farms can easily increase production capacity just by moving further out to sea. There will be less competition for land and freshwater resources, allowing these for national development/ urbanisation.

Century Aquaculture was set up in 2017 to research on types/species of tilapia suitable to acclimatise from fresh to seawater. The aim is to farm marine tilapia *Oreochromis* spp successfully in our local waters. We hope our efforts will help and contribute to Singapore's food security goals for 2030. It will also give our local fish farmers a better option and move away from either farming the low value milkfish *Chanos chanos* in waters off Lim Chu Kang or of the high value grouper or snapper (*Epinephelus* spp or *Lutjanus* spp) in waters off Changi. Additionally, we believe that we need a fish that offers an affordable source of protein for Singaporeans.

Fish farmers in Singapore have always faced stiff price pressures from farms in neighbouring countries such as Malaysia and Indonesia, where the cost of production is considerably lower than that in Singapore. Therefore, we needed to find ways to be more competitive, at least in supplying our domestic market.

There is a good local demand for the marine tilapia in Singapore. Consumers have accepted that tilapia farmed in seawater tastes better and is unique to the Singapore market. We believe that developing marine tilapia will not only help starve off price competition from neighbouring countries, but also offer better prospects for our coastal farms.

Developing a unique marine tilapia strain

In 2018, we embarked on a journey to search for a suitable strain of tilapia, with the assistance from two partners, trained tilapia and pangasius farming at the Asian Institute of Technology (AIT) in Bangkok, Thailand. We leased a small farm for this research and adopted the latest hatchery practices from AIT. Coincidently, when we took over the farm, we also "inherited" about 100 jade perch *Scortum barcoo* from the previous operator.

Some strains of tilapia that hatcheries claim can tolerate high salinity (30ppt) were tested. We stocked the fingerlings in open seawater cages off Lim Chu Kang but none survived. Most of the mortality was during the high tides, occurring every fortnight and fingerlings struggled to adapt to strong water currents. These were less than ideal water conditions with large fluctuations in salinity and temperature.

Tasty jade perch

Meanwhile, we tasted the jade perch that we had inherited. They were excellent whether steamed, grilled, baked or pan fried. Furthermore, although omnivorous, the jade perch is extraordinarily high in omega-3 fatty acids. We decided that we should produce fingerlings for the local market with assistance from the Singapore Food Agency (SFA).

After several failed attempts with different sources of tilapia, the farm decided to acclimatise the jade perch since some studies reported that it can tolerate salinities up to 30ppt. However, after numerous attempts, the conclusion was that once we reached a salinity of 18ppt, the fish could not survive. In 2019, I did the unthinkable by trying to cross breed tilapia and jade perch although biologically it would not happen since they are two completely different species of fish and the only shared similarity is that both are freshwater fish. Another assumption was that if breeding was successful, offspring would most likely be sterile.

Hybridisation of tilapia a jade perch

After a long wait of about 2 months, we produced the first batch (F1) of hybrids. However, the fingerlings (F1) were odd in terms of shape and colour. Nevertheless, we continued to get a batch of F1 fish every other month. This was the start of our hybridisation program in 2020. We spent the next two years studying and documenting this process.

Currently, we have the 4th generation of the hybrid and a few hundred female broodstock to move to the commercialisation stage (pending regulatory approval). Below are the findings that we have documented over the past 2 years.

Appearance

It was apparent that the tilapia genes were dominant as the first and second generation hybrids look very much like the tilapia. There are variants in colour: orange, black and silver. The 4th generation is taking more of a hybrid shape, presumably as the gene stabilises.

The land based farm for saline tilapia and jade perch at Century Aquaculture uses full seawater.

Characteristics of the hybrid

This is where we noticed marked differences from the tilapia.

a. Male to female ratio was 95% to 5% (similar to jade perch)
b. Egg production was more than 3000. This was the maximum based on current observation for a 200g female.
c. Adaptation to salinity is from 0 to 38ppt, which means that the hybrid can be farmed in both freshwater and full seawater. Fingerlings can also tolerate rapid increases in salinity from 0 - 35ppt within a week.
d. Growth of a 2-inch (5.1cm) fingerling to 450g is 5 months, based on a current open sea cage trial.
e. Flesh is firm and sweet with no muddy off flavour. This is similar to jade perch which consumers say tastes better than the red snapper.
f. Survival rates have been recorded at 98% in cement tanks.
g. Survival for swim outs is 95% indicating the ability to feed on artificial diets.
h. Survival in extreme conditions was evaluated with the following parameters - high stocking density using 2-inch (5.1cm) fingerlings at 25kg/m^3 in 25ppt seawater (Table 1).

Parameter	Minimum values	Observations
Dissolved oxygen	Survive in 0.5mg/L	Over 72 hours, zero mortality
Ammonia	40ppm	Tested over 3 months, zero mortality
Nitrite	25ppm	Tested over 3 months, zero mortality
Temperature	17°C water	Tested over 7 days, zero mortality
Food	No feeding	Over for 4 months, zero mortality
Combination of DO, NH_3 and temperature	Mortality	Mortality is 50% over 48 hours

A preliminary test conducted by Republic Polytechnic, Singapore, in October 2022, showed that the hybrid is a 90% crossbreed. It is waiting for grants to run a full test on the fish.

Based on the above findings, we believe that the potential of this hybrid is enormous. The hybrid is not only a very hardy fish, but very economical to farm. Feeds for the tilapia will suffice to achieve good growth. With rapid urbanisation in many countries and also the pressing need to feed the growing world population, this fish might an alternative for marine farms.

More to uncover

Currently, we are conducting tests on the hybrid to determine whether it has a higher resistance against diseases that are affecting the tilapia. Theoretically, if there is a change in chromosomes (new genes from jade perch) there should be a higher resistance or immunity against common tilapia diseases. However, there is a lack of information on the jade perch since it is still not a widely farmed fish. I attribute the robustness characteristic of the hybrid to the introduction of jade perch genes. If this can be proven, the hybrid can be cross bred with popular strains of farmed tilapia to provide a "natural vaccine" for stronger resistance or immunity.

Next steps

Today, we are still in the process of selection for the broodstock to enable us to achieve a certain level of consistency in terms of shape and colour. We hope to accomplish this by the first half of 2023. There is still much to uncover on this new hybrid and whether all that we have achieved is scientifically acceptable. If so, we would like to be recognised that this achievement is probably the first of its kind in the world.

Joe Ng CW is the founder of Century Aquaculture Pte Ltd, Singapore.
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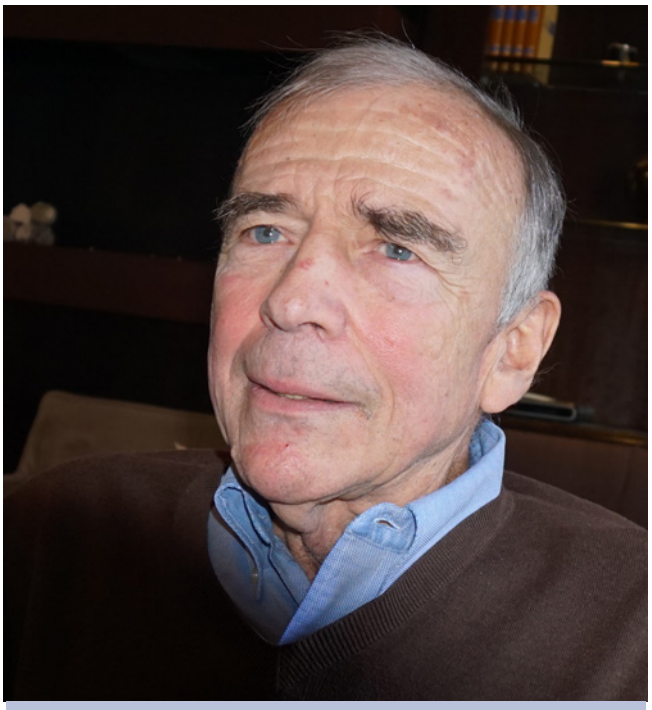
Tribute: A passion for disruptive aquaculture

By Regis Bador and Zuridah Merican



Alain Michel in 2017. Over the span of almost 50 years, Michel touched the lives of many aquaculturist worldwide.

In the early days of his career, **Alain Henri Michel,** aquaculture researcher and consultant, worked on domesticating the marine shrimp but with a special dedication to the blue prawn *Penaeus stylirostris*. In his later years, he focused on disease management, specifically heat shock protein treatment for controlling diseases in the Asian seabass or barramundi *Lates calcarifer*, tilapia *Oreochromis* spp and white shrimp *Penaeus vannamei*. Over the span of almost 50 years, Michel touched the lives of many French researchers, who at twenty-something were just starting their aquaculture careers as well as many others worldwide. Alain Michel died on June 11, 2022, in Versailles, France. He was 85.

The announcement of his death led to a sharing of memories by the global aquaculture fraternity in LinkedIn, many of whom are now in their fifties and sixties. The recent World Aquaculture 2022 in Singapore was an opportunity to recall the work of Michel and his coworkers, its significant influence on aquaculture today and to pay tribute to Michel's colourful aquaculture career. The significant lesson that we learnt from him was, "Do not hesitate to be disruptive and to exchange information, acknowledging the contribution of each participant, in a team spirit."

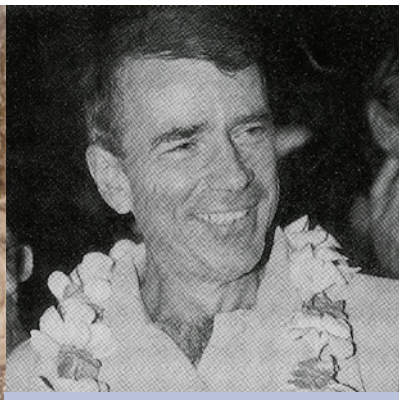
Regis Bador, a consultant in New Caledonia, who singlehandedly organised this session on December 1, said, "This was a special session rich in passions (and emotions) through 4 complementary presentations, followed by an interactive debate on how to anticipate, avoid and mitigate disease outbreaks and chronic disease expression in tropical aquaculture."

He added, "Acknowledging the benefits of Alain's discovery of the heat shock protein treatment method to enhance the immune system of fish in the presence of a specific pathogen was a must. This method is becoming a standard for many fish farmers in Asia and Africa, even if it is not 100% efficient."

Regis recalled how in 1984, he was hired by Michel to be his direct assistant at IFREMER in Paris for 2 years, after the completion of his military obligations at COP in Tahiti. While Regis had left IFREMER in 1991 to dedicate himself to private shrimp projects worldwide, Michel recommended Regis to be the farm manager of the largest shrimp farm in New Caledonia in 1998. They both remained close until his death.

The early years with domestication and IHHNV

Michel's story is also that of the scientific and technical team of the Centre Océanologique du Pacifique (often referred to as "Aquacop"), part of the French government institute CNEXO-IFREMER, located in Tahiti, French



Centre Oceanologique du Pacifique (Aquacop) in Tahiti in 1978. Alain Michel in 1972 as Aquaculture Head at AquaCop.

Accepting the commemorative plaque from Anne Denis-Blanchardon, French Deputy Ambassador in Singapore.

Polynesia. Michel joined COP in 1972 and was the scientific director until 1984. After 2 years at IFREMER's Paris headquarters, he became its director from 1986 until 1990.

There were many firsts in aquaculture at COP. In the 1980s, it pioneered eye stalk ablation, the mass production of post larvae in hatcheries from captive shrimp, freshwater prawn hatcheries in clear water in the 1980s and the development of biofloc technology. Its biologists transferred their technologies to many tropical countries through private or public partnerships across the globe with France Aquaculture (a subsidiary of CNEXO-IFREMER, which was created as the conduit for development projects). Through the Semacua vannamei hatchery and later another one in Ecuador in 1982-1983, the team played a significant role in shrimp farming in the Americas, showing the path to so many more hatcheries based mostly on the same design and operational principles. There were also other shrimp hatcheries in Colombia, Mexico, Indonesia, Thailand and Madagascar.

Eye stalk ablation was developed because of Michel diving into tanks to observe broodstock behaviour. One day, he saw that each time a female had one eye missing, it was quite mature and, remembering an old French publication, he squeezed the eyestalk of non-mature females and they were ready to spawn a few days later. His principle was, "It is always important to look carefully at your animals daily, watching their behaviour. Looking at them allows you to prevent many problems before they become serious and to react quickly."

In the 1980s-1990s, Asia benefited from those early experiences and know-how. Teams from Aquacop spent over 14 years with Fega Marikultura setting up the first *Penaeus monodon* hatchery (and a farm) in the Seribu Archipelago in Indonesia and among others, a pilot hatchery for freshwater prawn and marine shrimp with the Malaysian government, a maturation facility with San Miguel Corporation in the Philippines and a training centre for shrimp in Sri Lanka with the Asian Development Bank.

Domesticating blue shrimp and IHHNV

A young Marc Le Groumellec was brought in to replace Dr Maurice Weppe, a pathologist based in Tahiti, who had been sent to Mexico to develop some *P. stylirostris* strain after the SPR43 strain produced in Tahiti. At the tribute session, Le Groumellec described how the young team in Tahiti and New Caledonia worked in the domestication and reproduction of *P. stylirostris*. Later, Le Groumellec headed the Madagascan domesticated *P. monodon* project at Aqualma/Unima. Many other projects were then developed on a similar model. This project in Madagascar with visionary owners have been real game changers in both the production technology and marketing strategy of cultured *P. monodon* after the early success of Fega Marikultura in Indonesia.

"In Tahiti, we imported stocks to expand the genetic diversity of the founder stock. We systematically stocked survivors and crossed to develop Tahiti's very own domesticated stock. This population was resistant to IHHNV (infectious hypodermal and haematopoietic necrosis virus), carrying the virus at low levels, while other populations were highly sensitive. That was when we developed the hypothesis of a low virus load could be protected against serious infection. This strain was then named SPR43."

Then in 2005, over in New Caledonia, a genetic program was initiated to correct the possible negative effects of inbreeding. An SPF/high-health *P. stylirostris* population was imported from Hawaii. Crossing pure SPF and crossed SPF X SPR stocks, the "newly developed" stocks experienced signs of typical IHHNV infection,

"In aquaculture, it is a utopian dream to fully exclude pathogens from the environment; they are part of the aquaculture equation and so we should find a way to live with them."

Immediately after the tribute, a tasting of blue prawn from SOPAC, New Caledonia, prepared in two different ways by Chef Felicien Cueff. Alain Michel was one of the key deciders in the early 80s to select Penaeus stylirostris as the best-adapted species to local specific conditions of New Caledonia.

From 2000, for over 16 years, Alain Michel spent periods of six months working on cage farming the barramundi at Fega Marikultura's Jukung Island which had tanks for broodstock, hatchery and nursery. From top left, anti clockwise, observing broodstock in indoor tanks, with Farm Manager, Bambang Wahjudi; barramundi schooling behaviour enhances spread of diseases.

showing that the tolerance of the SPR43 strain to IHHNV had a genetic basis and was potentially reversible if important polygenes were lost during the "new blood" introduction. Facing a progressive increase of IHHNV infections in those "new" stocks in 2008, local partners decided to destroy them and keep only the successive generations of "pure" SPR43. This is the *P. stylirostris* stock which is still successfully reared after 40 generations today, thanks to pathogen resistance and adapted production practices.

Inbreeding was an issue which Michel continued to question. "Geneticists always talk about the need to have genetic diversity from many families. Is inbreeding such an issue when strains are already providing good service?"

In Ecuador, a survey related to the presence of IHHNV in three major shrimp-producing regions in Ecuador, namely Guayas, El Oro, and Esmeralda, showed that IHHNV is endemic (3.3–100% prevalence) in shrimp farms. Dr Luis Fernando Aranguren Caro, University of Arizona's Aquaculture Pathology Laboratory, reported that experimental bioassays using specific pathogen-free (SPF) *P. vannamei*, *P. monodon* and *P. stylirostris* and representative IHHNV isolates from Ecuador and Peru, showed that the virus did not cause any mortality or induce clinical signs in any of the three penaeid species presently reared in these regions. Interestingly, the currently farmed *P. vannamei* lines in Ecuador are tolerant to circulating IHHNV genotypes and bioassay data showed that, although the currently circulating genotypes are infectious, they do not induce clinical lesions in the three commercially important penaeid species.

In 1989, France Aquaculture became Sanofi Aquaculture (SA), when Sanofi, a French pharmaceutical giant entered aquaculture. It began developing new hatcheries and farms. Michel became General Manager in 1990. With Betagro, Sanofi bought and redesigned an existing farm and set up a new hatchery near Nakhon Si Thammarat, Thailand. A successful first crop (20 tonnes/ha) was followed by yellow head disease (YHV) and white spot syndrome (WSSV). For Alain, the hit was too sudden to quickly find a solution. It was time to go back to research, but business owners were not ready to wait for results and the projects closed.

The later years: Jukung Way with heat shock protein treatments

From the late 1980s, Michel and his team at IFREMER worked on farming and reproducing the barramundi in captivity. After his retirement in 2000, for over 16 years, Michel spent periods of six months working on cage farming the barramundi at Fega Marikultura, which moved to this fish after its shrimp business was devastated by WSSV.

It was here that Michel observed the serendipity effect: when observing larval fish infected with viral nervous necrosis (VNN), he saw that they were well and eating when the heater malfunctioned, raising the water temperature. Deeply observing the situation and analysing it, he just had empirically discovered that infected larval fish could be treated with heat-shock treatments (over a short period when juveniles were in the early stages of a disease) and proposed a new paradigm. This is the "Jukung Way"- a pragmatic approach developed mainly by trial and error through the observations of the skilled Fega technicians smartly managed by Alain. This result is explained by the effect of heat shock proteins which are chaperone proteins upregulated by temperature shocks (Michel, 2017b).

"It is an innovative approach of vaccination in 'live strengthening' of the juveniles at the nursery step through contact with the pathogen of the surrounding environment to prepare fish for transfer to sea cages. Well-trained and dedicated technicians can easily use this new tool at the commercial level. For barramundi and tilapia, survival can reach 80% dealing with VNN, different iridovirus, scale drop and big belly bacteria as well as Flexibacter," said Michel.

During The Aquaculture Roundtable Series on Finfish Aquaculture (TARS) in 2017, Michel went against the notion of the sterile environment model for juveniles and said, "Disease is a constant threat. Current production based on the biosecurity concept which relies on pathogen exclusion is a 'mission impossible'. In aquaculture, it is a utopian dream to fully exclude pathogens from the environment; they are part of the aquaculture equation and so we should find a way to live with them."

Tanks for heat shock treatment of juvenile tilapia in Ghana. In his later years, from his home, Alain Michel guided teams of veterinarians and farm staff of a Ghanian farm, 6,652km away, to use upregulation of anti-stress heat shock protein to halt the emergence of an iridovirus in tilapia.

Ten scientists who had benefited from Michel's experiences with the barramundi and tilapia presented an impressive summary of those findings and their impact. They said that methodologies were developed for heat-shock treatment against several diseases at the larval and juvenile stages of the barramundi. Once they were 5-10g, they were healthy, showed some resistance to various viral and bacterial diseases and could be vaccinated against *Streptococcus iniae* before being transferred to sea cages. A complementary approach of heat-shock treatment and vaccination has since been key to addressing major diseases observed during the farming cycle of the barramundi.

In 2019, a massive iridovirus outbreak wiped out almost the entire commercial tilapia production in Ghana's Lake Volta. In collaboration with a large commercial farm, Tropofarms, Michel developed a similar heating protocol to treat tilapia juveniles. This heat-shock treatment allowed the survival of tilapia that could subsequently be vaccinated at 10g against *S. agalactiae*, a bacterial pathogen found not sensitive to heat-shock treatments. Tropofarms continues to use heat shock therapy today and lives with the virus. Michel saved the tilapia industry in Ghana.

Michel continued to help farms in any way possible. In 2021, he wrote, "With travel restrictions during this pandemic, it is the internet that is helping to settle disease challenges. It has been matching scientific knowledge and fielding answers." Confined to his home, he described how he guided teams of veterinarians and farm staff of a Ghanian farm, 6,652km away, to use upregulation of anti-stress heat shock protein to halt the emergence of an iridovirus in tilapia (Michel, 2021).

It is unlikely that all diseases can be controlled by heat-shock treatments, which were most effective in cases of viral and bacterial infections. It is probable that the heat-shock treatment is effective in these cases because it reduces pathogen replication, allowing the fish to mount an immune response. In tilapia farming, like in barramundi farming, the major diseases can be controlled by a complementary approach of heat-shock treatment and vaccination.

Nevertheless, today the methodology developed by Michel is successfully used in many Southeast Asian and African farms with several tropical species. Over the past years, Michel had also been testing his methodology on other aquatic species, both temperate and tropical. Michel acknowledged that the exact mechanism of action of the biological pathways upregulation by hyperthermia is still not fully understood.

For example, Alain Michel reportedly tested hyperthermia as a tool to "control of white spot virus on *P. monodon* in Mozambique at Aquapesca", based on various scientific publications already showing that hyperthermia had an impact on tolerance. Although these experiments definitely showed a short-term effect on post-larvae tolerance to WSSV, it did not always last enough until the final harvest. Nevertheless, this method is still in use at that company. More recently, this strategy might have been successful against other pathogens, such as decapod iridescent virus 1 (DIV1).

Alain Michel is survived by his wife, May and two daughters, Barbara and Vainui, who said, "Not being an aquaculturist, my wish is for others to continue my father's pursuit of heat shock therapy and provide more information on its pathways."

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Positioning Taiwan's farmed fourfinger threadfin in local and export markets

A strategic choice of sustainable production technology is necessary to expand production and for the health and safety of consumers

Harvesting fourfinger threadfin in Taiwan. Photo credit: Dr Hsieh Chia Yu, Dept of Veterinary, National Chung Hsing University, Taiwan.

Taiwan has an active aquaculture industry with 50 species, including tilapia, milkfish, oysters, Asian sea bass, various groupers, shrimp and fourfinger threadfin. Its consumers enjoy seafood and the average consumption of fish and/or seafood products per year is estimated at 35kg/capita (USDA, 2021). In comparison, the global average of fish consumption was 20.2kg/capita/year (FAO, 2022).

In 2021, the top five farmed species (tilapia, milkfish, groupers, Asian sea bass and fourfinger threadfin) comprised close to 90% of Taiwan's total farmed fish production of 275,000 tonnes. Currently, around 60% of fish supply is from aquaculture which is expected to continue growing with increasing demand for high-quality seafood. There are 43,000ha of aquaculture farms.

Currently, the delicious fourfinger threadfin is one of Taiwan's most popular aquaculture species. It has become a farmed species of economic importance in Taiwan, said Professor Lin Han-Jia, National Taiwan Ocean University and President of GiantBiotech, in his message at the opening of the Third Marine Fish Farming Technology Forum, held on September 29, alongside the Taiwan International Fisheries and Seafood Show (TIFSS) 2022. There was an active interaction between the industry and academia to address how to overcome technical problems in its farming and how Taiwan can maintain a lead. The goal is to move towards a sustainable and profitable industry. The annual output of fourfinger threadfin is 13,000 tonnes valued at TWD 3 billion (USD97.8 million).

Chen Chien-Yu from the Fisheries Agency, Council of Agriculture, Executive Yuan (FA) presented on the current status of fourfinger threadfin farming and discussed some directions to increase production. Aquaculture in Taiwan is generally a small family business. Chen said that the average age of the first generation of Taiwanese farmers is now around 57.3 years. As such, FA is encouraging the younger generation to take over their family's aquaculture business. Furthermore, the older generation have difficulty adopting new technology.

Trends in farming the fourfinger threadfin

The fourfinger threadfin belongs to the Polynemidae family. In Taiwan, there are two main species of the fourfinger threadfin. The main farmed species is *Eleutheronema tetradactylum*, originally from Singapore and the Philippines. Known as a tropical Polynemidea, 90% of production is from Pingtung County on the southwest coast of Taiwan, mainly because the average temperature of 25°C to 30°C is ideal for its farming. The fish grows very fast during its early stages. Market size can be as small as 150g fish. However, in general, farmers produce 250-300g over a production cycle of between 6 to 8 months. The other species available in Taiwan is the sub-tropical *Eleutheronema rhadinum*, which is usually caught in estuaries.

Red fin is a common disease of fourfinger threadfin (left) and lesions on the skin are common. Photo credit: Dr Hsieh Chia Yu, Dept of Veterinary, National Chung Hsing University, Taiwan.

In Pingtung County, this threadfin is generally farmed in concrete ponds. A negative aspect of its farming is the high stocking density, cited by Chen at a high of 170,000 fish/ha to a low of 100,000 fish/ha. The fish requires high levels of dissolved oxygen and aeration is provided by paddlewheels. It also has a nervous disposition and easily reacts to disturbances with erratic behaviour resulting in physical damage to the fish body surface. This characteristic makes high-density farming risky.

In high-density farming, incidences of diseases, such as red fin and sometimes lesions on the skin are common. The risk is that farmers will then begin to use antibiotics. Health authorities must check on residues at harvest. In the threadfin farming, antibiotic residues are higher when compared to other species. Chen said that in such instances, the value of the product is low, which the farmer does not consider during the culture period. FA says that it also must deal with issues of traceability.

Domestic and export markets

Most of the threadfin production is mainly for export (Figure 1). The ratio is 1:4 (local consumption: export). China is the major export destination and Chen expressed concern with this reliance on trade with one market, exemplified by the recent incident with Taiwan's grouper exports to China. In June 2022, China imposed a ban on grouper imports citing the presence of banned substances in some shipments. "If our fourfinger threadfin industry faces the same situation, how would FA handle this issue?"

The domestic market absorbs 3,000 tonnes of the fourfinger threadfin production. In 2020-2021, sales in the domestic market increased as consumers learnt to cook at home during the Covid-19 pandemic. During these two years, there was a promotional campaign to encourage local consumption of the fish. Some initiatives included communicating with consumers on the health, safety and nutritional benefits of the fish.

According to Chen, the fish size in the domestic market is from 226g to 320g, In the past, Taiwan also exported to Singapore and other parts of Southeast Asia, but these markets would require 1.2kg fish, which will require a 2-year culture cycle.

Positioning the fourfinger threadfin

Taiwan's threadfin competitors are China and Malaysia which have overcome challenges in farming technology. Their advantage is large farms and lower costs of labour. Therefore, Chen said that there is a need to find ways to differentiate Taiwan's threadfin, away from the low-cost strategy of China. It is expected that China will catch up with Taiwan in the farming of this fish in 2-3 years.

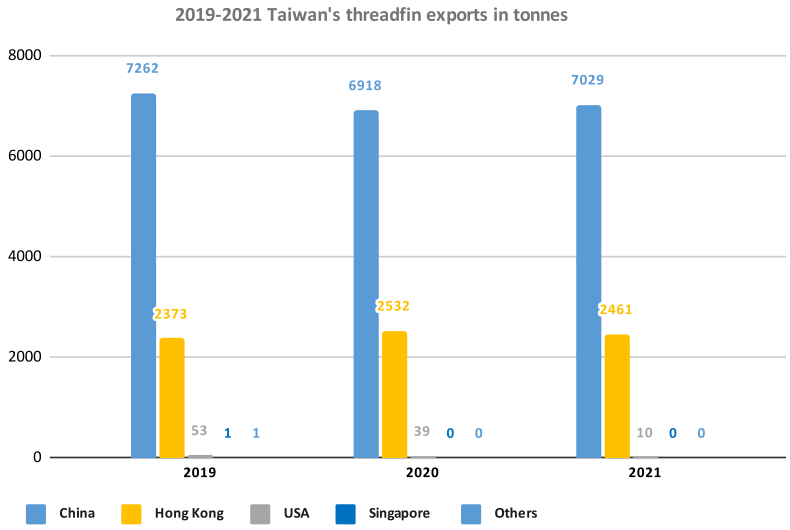


Figure 1. Taiwan's threadfin exports in 2019-2020. Source: The characteristics and development of Taiwan's fourfinger threadfin industry, presented by Chen Chien-Yu, Fisheries Agency, Council of Agriculture, Executive Yuan (FA).

Taiwan needs to adhere to its strength of producing certified high-quality products with less use of chemicals. The first step is the registration system for domestic and export sales and applying for the Aquaculture Stewardship Council certification (ASC).

In his presentation, USSEC's Hsiang-Pin Lan described the steps for certification to increase market access for Taiwan's seafood products. He cited advantages such as learning from and being in line with international standards. Cluster certification will help small-scale aquaculture farms.

Chen promoted the thinking of producing the "less is more" concept, given the example of the milkfish farming industry which has been using the most optimal stocking density. It has managed to reduce risk and achieve sustainable operations without an impact on selling prices. The use of probiotics to replace chemical treatments is encouraged.

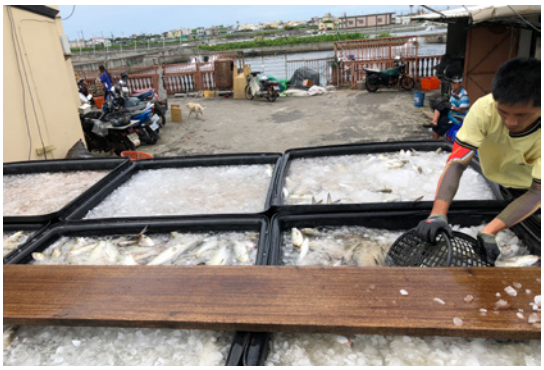
Taiwan also has an advantage with a cold chain where fish will arrive at the qualified HACCP and ISO22000 packing plants within an estimated 30 minutes. Over 2010 to 2013, the government has implemented some cold chain projects, including in Pingtung County to encourage as well as expand, the processing of various products. This is also directed at expanding to markets in Southeast Asia and other countries and having different threadfin products according to market demand. This follows a trend with the grouper, where the different product formats could reduce risks.

There are farm management challenges, such as culture management, food safety, traceability and fry and feed production. Relating to farm management, FA would like to develop standard operating procedures (SOP) to monitor the full traceability of the supply chain. This includes controlling the use of antibiotics. It also wants to encourage farms to maintain the most appropriate stocking density.

Innovations in farming

You-Ying Chen is the founder of Three-Fishes Grocery and a farmer from the Hundred Young Farmers group, who has been farming the fourfinger threadfin over the last 6 years. At this forum, he gave some perspectives on the challenges and views on how to innovate to an industrial scale farming of this fish. Comparing with salmon production in Norway, Chen said that the cost of production of the salmon is lower than that of the fourfinger threadfin and giant grouper in Taiwan. For the threadfin to be a leading product of Taiwan, its farming technology should be upgraded, both for quality and quantity production.

Chen commented, "Despite the level of production, no feed manufacturer is producing a dedicated feed for this species. Fish is fed a general marine fish feed. To achieve a larger harvest size, such as more than 600g, the stocking density should be lower. Risks are in fish health management and diseases, which significantly increase if large harvest sizes are desired. There is no selective breeding program for this species."



Clockwise from top left, a threadfin farm; harvesting and chilling threadfins. Photos courtesy of Eliza Lin, Giant Bio Technology, Taiwan

The market segments for this fish must be expanded and space must be created for larger market size fish to produce steaks. The largest size fish that Chen has harvested is 600g which took him 1.5 years. The cost of production was high and culture was at low density, such that the harvest was only 2,400-3,000kg in an area of just under 3,000m^2 without the use of antibiotics. Chen asked whether the consumer is willing to accept the much higher prices for larger fish, although Taiwanese consumers have the spending power. However, giving consumers the choice of fish sizes from 300g to 600g will help the farmer organise his production cycle.

Chen and the young generation of farmers in his group are conscious of the 17 UN SDGs, in particular the social responsibility and ocean sustainability for the whole industry. Therefore, Chen practises semi-intensive culture of the threadfin, providing the fish with a better environment and larger space. Currently, he is running a trial using probiotics and the Chinese herbal product Fish Balance in the ponds to maintain fish health during the first 3 months of the culture cycle.

Repositioning markets for the fish

Chen proposed to move away from a single-market sales model. "We reposition the fish away from the table-sized fish market segment to a range of sizes, but who are the buyers and how can the fish be sold?" He brought in a social responsibility element which is to encourage local consumers to visit and appreciate the hard work that goes into farming the fish and the food safety aspects. "This is also to increase the willingness of consumers to pay the price of the fish. In community development (SDG#11), Chen mentioned the need to create jobs to draw young people to the fishing villages and replace the ageing farmers.

Creating a brand for Taiwan's fourfinger threadfin can be done at local and international levels. It could be company brands by large farms for the domestic market and for export, a national branding such as 'Taiwan fourfinger threadfin'. However, Chen is more aligned towards the 'Pingtung Fourfinger threadfin' brand as it reflects the place where the fish is farmed, giving it exclusivity.

New production models

The team from the National Chaiyi University, led by Professor Hong Thih Lai, has been working on sustainable farming models for other farmed species and has plans to look at models for the fourfinger threadfin. The presentation focussed on addressing the rising costs of feed and power inputs. With the latter, the target is to use solar photovoltaic (PV) cells to reduce energy costs and move towards renewable energy. Models were developed on the positioning of solar panels in open ponds. The results differed and it was concluded that harvest yields depended on the species and farm management. The team also considered alternative protein options, such as plant sources to insect meals, to reduce the inclusion rate of fishmeal in feeds.

This forum was comprehensive in setting out the future direction in the farming of the fourfinger threadfin in Taiwan and its marketing. Lin said that while the future ambition is considered quite large, at the moment it requires the cooperation of industry, government and academia to work together to solve current problems. NTOU has agreed to lead this initiative on how to balance sustainability with profitability.

Acknowledgements

This report is based on some presentations at the Third Marine Fish Farming Technology Forum, subtitled in English by the team at NTOU. We are very grateful for the additional assistance of Hsiang Pin-Lan, USSEC Taiwan in the preparation of this report and to Dr Hsieh Chia Yu, Dept of Veterinary, National Chung Hsing University, Taiwan for photo illustrations.

The 2023 Taiwan International Ocean and Fisheries Industry Show (TIOFIS) will be from August 31-September 2 in Taipei.

References are available on request.

Mastering the microbiome in ponds in Vietnam

Ruben Props (left, back) and Marc Indigne (third left) with the KYTOS team from Belgium and Vietnam (Jonabel Huaves and Ngan Bui) at World Aquaculture 2022 Singapore. In 2022, it established a strategic partnership with I&V BIO to bring its technology closer to the shrimp industry.

Fish and shrimp ponds are home to thousands of microbial species. However, how do we take control of the microbes in the pond water, biofilter, sediment, or even in the gut? Do the prophylactic products, additives or biocontrol products that are commonly added to ponds have a beneficial effect?

KYTOS is a spin-off company from Belgium's Ghent University and specialises in offering revolutionary microbiome management services to the aquaculture industry. Their mission is to make microbiome management smarter, easier and more accessible. Kytos is now proud to offer their services to the Vietnamese market. In 2022, it announced that it has processed 59,425 samples via its microbiome management platform.

A healthy microbiome = a healthy crop

The microbiome is present all around a pond. It can be found in the rearing water, in the animal and the sediment. This microbial community consists of viruses, bacteria, algae, fungi and other microscopic organisms. The products farmers use on their farm, such as prebiotics, probiotics, synbiotics, different diets and disinfectants all influence the microbiome health of their ponds. While disinfectants may selectively kill microbes, pre- and probiotics may promote the overall function and resilience to disease outbreaks.

"Is it any wonder that the microbiome is very important to animal health and farm yield? Until recently, in the market, farmers had no tools to evaluate these effects," said Ruben Props, PhD, CEO and Co-founder.

"Our innovative technology provides a one-of-a-kind view on the pond microbiome and helps farmers at every step along the way to make informed decisions for the farm. Every individual microbe in the pond system is scanned using a high-tech technology while artificial intelligence translates the data into a comprehensive health assessment. We expand the view to all microbial life in the pond, including beneficial and harmful organisms. This means that we can give the farmer insights on 100% of the bacteria. This is more than the less than 1% that grow on agar plates. KYTOS technology casts light on the role of the microbiome in promoting animal health and the effects the farm decisions have on the crop."

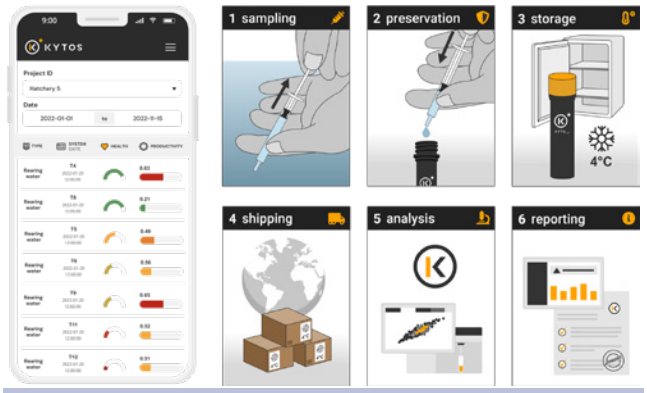
Microbiome management

Although disease outbreaks are always a top concern for a farmer, diseases do not appear suddenly. They are the ultimate result of cumulative stressors such as: poor water quality, overcrowding and overfeeding that have been building up over time. Often demonstrated is that disease outbreaks result from a complex interaction between the host, pathogen, and the environment. The aquaculture sector must pivot away from risky and anecdotal management strategies to science-driven management plans.

"Rather than only focusing on the disease-bearing microorganisms, it is essential to monitor the microbiome health from the beginning of the crop to take timely interventions to prevent a disease outbreak." said Props.

"As a farmer, we provide you with a holistic picture of the microbiome health in your ponds together with direct support from our microbiome specialists. We implement sampling programs for your systems and arrange all sampling materials and sample logistics."

The first data factory is located in Phan Rang and can process samples from all across Vietnam. The KytoVial sampling system enables biosecure microbiome sampling of the farm, by protecting both the farm and samples. The AI processes the microbiome data to provide the farm with next-business day results of up to 10 microbiome health indicators. Digital reports are accessible online and via the secure KytoApp mobile and browser applications. On top of the above, a renowned team of microbiome and aquaculture specialists are ready to assist the farmer in every step along the way, from stocking to harvest. www.kytos.com.vn.



The KytoVial sampling system enables biosecure microbiome sampling at the farm (left). Digital reports are accessible online and via the secure KytoApp mobile app (right).

Pump system for gentle transportation of fish and shrimp

From the left, Sit Kok Lee, Business Adviser; Jan Petter Urke, BU Manager Energy and Roy Glomset, Sales Concept Manager Process.

Norway's **MMC First Process** has a game changing pump system for moving fish and shrimp gently from point to point. A good example is transferring fish and shrimp between cages and ponds. It is also possible to use the system to move fish to a processing plant. This is part of MMC First Process's strategy to transform the seafood industry by providing sustainable solutions right through the processing chain from harvesting to cooling and processing. The company produces equipment for both aquaculture and wild catch fisheries.

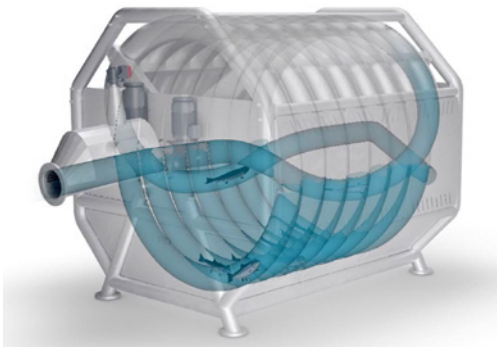
During the recent World Aquaculture 2022 Singapore, the team of Roy Glomset, Sales Concept Manager Process; Sit Kok Lee, Business Adviser and Jan Petter Urke, BU Manager Energy, discussed their latest product. It is an innovative spiral pumping system called the Aqua Farm RID Pump, designed to secure fish welfare and quality. This pump is the only such pump with a suction function and Glomset assured us that at no time will the fish or shrimp passing through it be deprived of water. The way in which the water is directed through the spiral pumping system ensures that fish and shrimp are fully immersed in water throughout the process.

"The smallest pump has a water flow of 64m^3/hour, while the largest is a high-capacity version where water flows at 1100m^3/hour. The large version can transfer fish up to a size of 10-15kg while the smaller pump is to designed to move small fry and fish up to a size of 1-1.5kg. These unique pumps are easily movable for positioning between tanks. They can also be stopped without harming the fish. There is continuous velocity and flow at both inlet and outlet," said Glomset.

These pumps have other advantages, in addition to bio security and animal welfare. "First comes energy consumption. The Aqua Farm Rid Pump is very energy-efficient compared to other known industrial pumping systems. Cleaning is safe and easy too. All that is required is to connect to the outlet and inlet. When used in a processing plant such as that for the pangasius, we reverse the pumping when processing stops."

The MMC First Process team said that this pump has enormous potential for fish transport and transfer. In Vietnam, trials are taking place at Viet Uc farm to transfer shrimp over 850m distances. Attached to the pump will be an automatic shrimp counter.

Staff at Atlantic Sapphire, an indoor RAS salmon farm, say they have observed that the salmon recover their appetite more rapidly than usual after transport with this system. This indicates that the fish were not stressed. Glomset said, "At an early stage, we worked with researchers in Norway to prove how effective the pump is for fish welfare. The team from SINTEF ran tests using sensors to measure pressure surges and shocks through the pump. Another research group took blood samples and analysed them for lactate concentration, which is an indicator of stress. Results showed that the stress level in the fish was well below the recommended threshold." https://www.mmcfirstprocess.com/aquafarmpump



Aqua Farm RID pump system is for gentle transportation of fish and shrimp. A video of the pump with fish passing through is available on youtube.com (MMC FIRST PROCESS - RID FISH PUMP - YouTube (https://www.youtube.com/watch?v=zcbqWdg0ZHM)

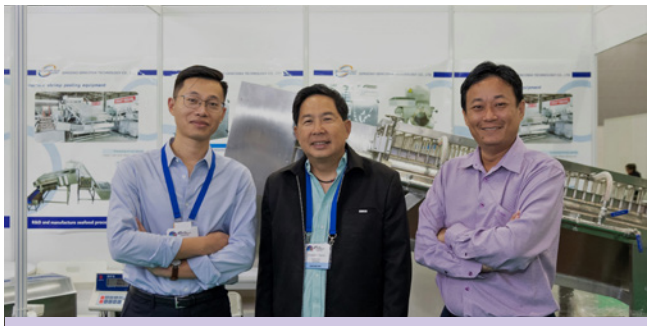
A successful World Aquaculture 2022 in Singapore

Initially planned in 2020, the World Aquaculture 2022 Singapore finally happened from November 30 to December 2. As the President of the World Aquaculture Society (WAS), Dr Jennifer Blair, said in her column on the WAS website, "It was a fabulous return to a face-to-face international aquaculture conference in Asia. There were 3,592 people attending, representing 82 countries and a technical program with over 400 presentations in 58 sessions."

The event was hosted by Singapore Food Agency and Ms Grace Fu, Minister for Sustainability and the Environment opened the conference and trade show on November 30. In her welcome address, the Minister said that innovation and technology are enablers to transform aquaculture and this is particularly critical for Singapore which imports 90% of its food. Singapore has set '30 by 30' goal to build the capabilities and capacity to sustainably produce 30% of its nutritional needs by 2030.

"We are uplifting the aquaculture sector with the Singapore Aquaculture Plan (SAP) in three ways. First, we will find new spaces for aquaculture. Second, we will transform the industry with technology and better farm practices. Thirdly, we will invest in research and innovation for sustainable tropical aquaculture."

There is the commitment of SGD60 million (USD45.4 million) by SFA to the Agri-Food Cluster Transformation Fund to co-fund the adoption, test-bedding and development of productive, resource-efficient and sustainable farming technologies and systems. This includes technologies and systems that help farms make predictive and informed decisions in optimising resources and increasing productivity. The Government has also committed SGD300 million (USD227 million) under the Singapore Food Story R&D program to drive research into sustainable urban food solutions, future foods and food safety science and innovation.



Zhang Wenlong, Qingdao Gencosea Technology who demonstrated a shrimp peeling machine at the show, with Constantine Tanchan, Choobi Choobi, Philippines (middle) and Sim Ing Jye, Sea Horse Corporation, Malaysia (right).

The Singapore Pavilion gathered enterprising aquaculture companies and new innovators.

Benny Shapira, Global R&D Manager – Phibro Animal Health Corporation Israel (left) with Masahiko Yamada, Co-founder/ Managing Director at UMITRON Pte. Ltd

Nabil Hamid (second right) with Joe Kearns (middle) and team. Grand Aqua Group was a premier sponsor of this event

Singapore aspires to be the aquaculture research & innovation hub of Asia. "AquaPolis" is a research and innovation cluster for Tropical Marine Aquaculture, jointly led by SFA, the National University of Singapore, Temasek Life Sciences Laboratory and industry partners. A memorandum of understanding was signed with seven local industry players. SFA's Marine Aquaculture Centre (MAC) at St John's Island will be the nucleus and an active collaboration with institutes of higher learning and research institutes.

Ms Fu also launched the Singapore Standard: Specification for Clean and Green Urban Farms for Aquaculture today. This Standard was jointly developed by SFA and Enterprise Singapore, together with the industry, retailers and Institutes of Higher Learning under the purview of Singapore Standard Council. The aim is to guide local aquaculture farms to produce food in a clean, safe and resource efficient manner, through the adoption of smart farming techniques, reducing farm waste, conserving resources, incorporating circularity and raising operational efficiency.

Dr Matthias Halwart, Team Leader Sustainable Aquaculture – Global and Regional Processes team of the FAO, provided a plenary presentation at the conference entitled Aquaculture for Food Security and Sustainable Development. Two WAS awards were presented at WAS22. Dr Farshad Shishehchian was awarded the 2020 Industry Impact award for his more than 30 years of dynamic, hands-on experience in the world's top aquaculture-producing countries, managing aquaculture farms and hatcheries in different locations. Dr Sungchul (Charles) Bai was named as a WAS Fellow. He has over 35 years of teaching, research and industry consulting experience and he currently works as a professor at Pukyong National University.

Tradeshow

"The Trade Show was impressive, with 264 booths and a Singapore Pavilion as a centrepiece to highlight local producers, innovative technology, scientific capability and government agency research and development services," said Blair.

Aside from SFA (www.sfa.gov.sg), the Singapore Pavilion hosted several farming enterprises, research and higher education institutions involved in aquaculture. There was the **Aquaculture Innovation Centre (AIC)**, established in 2019 by Enterprise Singapore. The aim of AIC is serving local aquaculture farms with their production needs through project consultancies, research in innovation and technology development, testing services for farm biosecurity management and manpower development. AIC is hosted by Temasek Polytechnic. (see article in issue Nov/Dec 2022, p59).

Temasek Life Science Laboratory (www.til.org.sg) hosts global talent to undertake cutting edge biomolecular science research for the benefit of the Asian region. The team at **Republic Polytechnic (RP)** is developing a selective breeding program for the red snapper species. With The Fish Farmer, it is working to improve the growth rate and colouration of the species. In this collaboration, The Fish Farmer will hold the brood stock of genetically selected red snapper and supply the fingerlings to other local farms, lifting the quality of red snapper farmed in Singapore.

At the Aker Bio Marine booth. From left, Chaiyot Rawekchom, Regional Sales Director QRILL Aqua; Atul Barmann; Lena Burri and Bawanta Suta, Aquaculture Sales Manager, Indonesia. Chaiyot was rather pleased at the activity at this trade show and at the chance to meet customers from across the region face-to-face. Many came to discuss the use of krill meal for their shrimp and marine fish feeds. At the conference, Burri presented a poster reviewing the latest studies with krill meal that were performed in Brazil, Thailand and India. (see article on page 28).

Phileo by Lesaffre's Alban Caratis (middle) and team, presented work on its new generation multi-strain Bacillus spp. feed probiotic on survival, health status and economic results of the white leg shrimp reared under super intensive conditions and on the yeast-based immunostimulant in an S. agalactiae challenge.

Aquaculture America 2023

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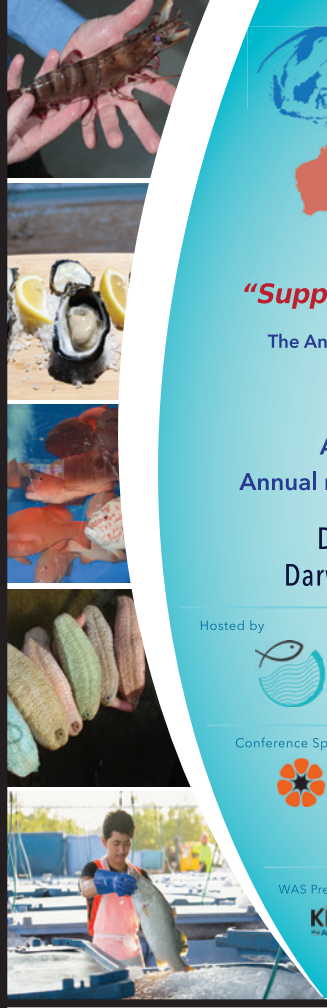

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Lusaka, Zambia

Second African Aquaculture Event, 2023
organised by the
African Chapter of the WAS

World Aquaculture Society
Conference management - worldaqua@was.org
Trade show – mario@marevent.com
www.was.org

Farming enterprises included **Aquaculture Centre of Excellence** (ACE, www.ace-com.sg) and founder and CEO Leow Ban Tat, wants to change the way the world farms fish. It uses technology to revolutionise marine fish farming in a sustainably in floating arks (see article in issue Nov/Dec 2022, p60). **Vertical Oceans** (www.verticaloceans.blue) uses sensors, smart devices and real time learning algorithms to farm shrimp in vertical towers with small footprints. The systems will grow clean seafood in cities close to markets.

Barramundi Group (www.barramundi.com) farms Asian seabass off the southern waters of Singapore and has farms in Brunei and Australia to deliver premium quality ocean farmed barramundi under its Kuhlbarra brand. It reported production volumes of 1,500 tonnes in the first 9 months of 2022. It was listed on the Euronext Growth Oslo in August 2021, the first for an Asian aquaculture group. **Blue Ocean Aquaculture Technology** (www.finbyboat.com.sg) says it uses nano oxygen to farm jade perch and hybrid groupers indoors. This a vertical indoor RAS which does not use liquid oxygen towers. **UVAXX** Pte Ltd (www.uvaxx.com) develops autogenous vaccines for the Asia Pacific region. It works in close partnership with small and large aquaculture operators which enabled UVAXX to develop and implement real-world fish health management strategies and tools that work.

Unique to this year's tradeshow was also several startups based in Singapore. The country has an active startup in aquaculture ecosystem. Prior to the event, HATCH, the aquaculture accelerator with offices in Singapore, Hawaii and Norway, organised a SG innovation studio supported by the Startup SG Accelerator Grant program by Enterprise Singapore. Nine innovators participated and following this, some had booths at the tradeshow.

The **Forte Biotech** team has been working in Vietnam as it provides solutions to allow shrimp farmers to earn more. Its easy-to-use farm-side diagnostics can provide PCR grade readings within an hour. www.fortebio.tech (see article in issue Sep/Oct 2022, p55-56).

Peptobiotics provides the cheapest recombinant peptide production in the world. It can produce sophisticated peptides with challenging secondary structure at costs that are competitive for livestock and aquaculture additives - up to 100,000 times cheaper than chemical synthesis. The current product is a prophylaxis against EMS/AHPND. www.peptobiotics.com

Living Seas Aquafeeds uses marine microalgae as a feedstock. It is pioneering a proprietary process of bio enhancement and refinement of seaweeds to increase the bioavailability of amino acids and marine minerals. In aquafeeds, these improve animal health and feed conversion ratios (FCR), reduce water pollution and carbon footprint. In Indonesia, it has functional aquafeeds with marine plant proteins to replace soybean and fish meals. www.livingseasaquafeeds.com

Inseact produces a high-quality protein insect meal as replacement of the tradional fishmeal for shrimp diets. Already in markets, their insect powered shrimp feed has shown significant improvements to feed conversion ratio, growth rates and survival against diseases. The BSF meal acts as an attractant. Inseact is a Singapore based biotech company, aspiring to bring value to the shrimp farming community in Asia. Its initial market are shrimp farmers in Southeast Asia. See their story on www.inseact.com

Singapore Aquaculture Technologies (SAT) is a sea-based closed-containment aquaculture farm which uses artificial intelligence, sensors and camera systems to determine fish size, monitor behaviour and detect feeding patterns. SAT operates fish farms and sells ethically farmed premium produce under its brand BluCurrent. At the SG innovation studio, SAT has next generation data-driven plug and play fish farms for floating and RAS land-based operations. www.sat.com.sg

There were several feed additives and ingredients suppliers at this year's tradeshows. Many were regular exhibitors at WAS events. Premium sponsor **Grand Aqua Group** is Egypt's newest aquafeed producer, set up by its Chairman Nabil Hamid in 2017. Grand Fish Feed has a feed partnership with US based Zeigler which provides formulation assistance, additives and guidance on related technical aspects. The company produces a range of extruded feeds for freshwater and marine fish as well as for the shrimp. The size range of shrimp feeds with 35-38% crude protein (CP) range from 0.5mm to 1.6mm. www.grand-aqua.com

Mary Ann Solis, Biosolutions Inc, Philippines with Neil Arvin Bretana, University of South Australia (middle) and Dr Roberto Cascione, Virbac, Thailand (right)

Erin Tan (right) and Sugania Vijayan (third right) with the team from Department of Fisheries, Brunei. 3 Little Fish has an innovative trapping device to reduce populations of leeches in cage culture. Other products are spawning inducers from Syndel.

Stephan Frouel, Innovation leader BU Feed Additives and Aquaculture Project Manager (right) and Pierrot Thomas, Global Aquaculture Manager (middle) at the MixScience booth. At the conference, Frouel presented on the preliminary response of a new feed solution to improve resistance of white shrimp post larvae against Enterocytozoon hepatopenaei (EHP). This is based on a 64-day trial in Vietnam.

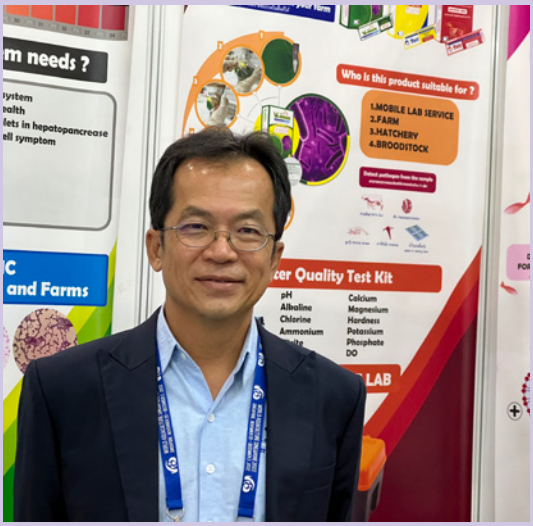
Alexanderos Samartzis, Director, Global Account Management, Evonik SEA (left) and Leicester Liu, Regional Marketing Manager (Asia Pacific South, second right) with M. Anbazhagan, Evonik India (third right) and Nguyen Van Tien, Evonik Vietnam LLC (right).

Higashimaru Co Ltd of Japan has extruded larval feeds for three species of shrimp: *Penaeus japonicus*, *P. monodon* and *P. vannamei*. These are exported from Japan into Asia. Protein levels in these feeds range from 52-53% CP and crude fat is 7-9%. It has introduced microencapsulated feeds for the zoea to mysis stages where the particle sizes are 5-30 microns for zoea and 30-50 microns for mysis. These have been shown to improve survival, promote growth and reduce feed residues. The company has a range of floating larval feeds for various marine fish such as the Japanese flatfish and puffer fish with 51-54% CP and 8-10% crude fat. The Higashimaru team is marketing these larval feeds for grouper farmers.
www.k-higashimaru.co.jp

At the Higashimaru Booth, Tsutomu Higashi, President (middle) with his team, from the right, Masataka Shoda, Deputy Manager-Fisheries Research; Kenichi Anraku, Deputy Manager – Aquaculture Feed Sales and Akibumi Iwasawa, Deputy Associate Director (left).

Working with Thai researchers to bring innovations to market

Based in Bangkok, **Marine Leader** Co. Ltd, is Thailand's leading producer and supplier of products for the regional's shrimp, marine fish, ornamental fish and prawn farming industry. The company is a regular exhibitor at World Aquaculture tradeshows. In line with recent demand from industry, Satit Phanich who set up Marine Leader in 2000, says that he has been working with several researchers in Thailand on new innovations and products to commercialise and bring to market. There is the shrimp ATK which is a rapid test kit for WSSV diagnosis as well as one for *Vibrio* sp. It uses immunochromatography assay to detect viral antigens. Using nanotechnology, an immersion vaccine has been developed against *Aeromonas* and another against the tilapia lake virus (TiLV). Satit said that these require a one-time application for fingerlings of 1-2 months old and will extend for 3 months. Top coating of feed with the vaccine is also recommended. Since most maturation facilities in Southeast Asia and China will require clean and high health polychaetes, Satit also offers consultancy services on farm design and farming of specific pathogen free (SPF) polychaetes. This farming requires excellent water quality and nutrition.
www.marineleader.co.th



Find sustainable solutions during VIV 2023

Since its founding in 1980 by Irish entrepreneur and scientist Dr. Pearse Lyons, Alltech has been providing smarter, more sustainable solutions for the agricultural industry. Its diverse portfolio of products and services improves the health and performance of plants and animals, resulting in better nutrition for all and a decreased environmental impact.

Alltech entered the Asian market over 30 years ago. The company maintains its deep connections throughout the industry as it brings global resources, experience and localised solutions to its customers in Asia.

At VIV Asia 2023, Alltech is excited to join more than 1,200 companies presenting the latest agriculture solutions, trends and technologies. VIV Asia, to be held from March 8-10 in Bangkok. is among the world's leading tradeshows dedicated to animal breeding and processing.

Alltech will showcase its solutions for improving animal health and performance while decreasing environmental impact. It will share how it is helping producers:

- Reduce feed costs and increase profitability
- Efficiently transform feed into food
- Take steps toward increasing sustainability by Working Together for a Planet of Plenty™.

The company will also host several events during the tradeshow, including:

- Alltech Happy Hour in booth No. 3410: 15:00–16:00 Wednesday, March 8 and Thursday, March 9
- Alltech VIP Dinner Reception downtown: 18:30-21:00, Wednesday, March 8 (by invitation only)

Alltech welcomes members of the Asia-Pacific aquaculture industry to join them at VIV Asia 2023 to discuss how to implement smarter solutions that will create a sustainable future for aquaculture.
www.alltech.com

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VIV ASIA 2023 Opens registration for Visitors

The most complete Feed to Food global trade show in Asia is finally back after 4 years

VIV Asia is the largest trade show in Asia dedicated to the world of livestock production, animal husbandry and all related sectors, from feed production, to animal farming, breeding, veterinary, animal health solutions, slaughtering and processing of meat, fish, egg, dairy products and more. Over 1,200 exhibiting companies will join a gathering of industry professionals from more than 120 countries. The show is scheduled from **March 8-10 at IMPACT** in **Bangkok**. The visitor registrations are now open.

Bigger venue, bigger business opportunities

In 2023, the show moves to a new venue reflecting an ever-expanding international exhibition. With its mega size, IMPACT offers room to welcome more global companies and business profiles thus enhancing the overall show experience for professionals from Asia and beyond. Its modern facilities support strategic development to take the show to the next level.

VIV Asia 2023 is co-located with Meat Pro Asia, Asia's leading processing and packaging trade fair for egg, poultry, meat, seafood and food products.

This debut edition of Meat Pro Asia is brought to life by the organisers of IFFA (Messe Frankfurt New Era Business Media Ltd) and VIV Asia (VNU Asia Pacific and VNU Europe). The coming together of two top industry players in the Asian region makes the show a must-attend for all the professionals in the entire animal protein supply chain.

For VIV Asia 2023, organisers offer an even easier way to travel to the venue:

- A free shuttle service to and from the venue has been organised, final routes will be published two weeks before the show on the VIV Asia website.
- Partnerships with some of the most renowned carriers to give all its participants an opportunity to book their airline tickets at the best price possible.

Conferences and sessions

VIV Asia 2023 will also be the knowledge hub providing an extensive program with around 100 sessions presented by partners from exhibiting companies, research institutes and industry associations. Participants can gain cutting edge know-how from around 200 high-level speakers from all over the world on various topics making the visit to VIV Asia 2023 a truly enriching experience. After a long halt, VIV Asia 2023 will come back bigger and stronger as the industry is looking forward to meeting again in person and to take on some of the most profiting business deals. For more information, visit the website www.vivasia.nl

AQUA CULTURE Asia Pacific

EDITORIAL CALENDAR 2023

Look out for AAP's annual report on trends in Asia's production of marine shrimp and aquafeeds

Volume 19	March/April	May/June	July/August	September/ October	November/ December
Deadlines - *Technical articles*	*January 17*	*March 14*	*May 16*	*July 18*	*September 19*
Deadlines - *Advert Bookings*	*January 24*	*March 21*	*May 23*	*July 25*	*September 26*
Innovations/ Startups	Experiences and opinions covering role models; clear and present needs of industry; innovations and digitalisation in aquaculture				
Interviews with industry leaders	Focus in 2023 will be leaders pushing for sustainable aquaculture				
Issue focus Emerging trends and challenges	Health & Disease Management	Sustainable & Responsible Aquaculture	Demand & Supply Equilibrium	Aquaculture Innovations	Health & Disease Management
Industry Review	Marine Shrimp	Aquafeed Production	Tilapia	Marine Fish	Catfish & Freshwater Fish
Feeds & Processing Technology	Fish meal/oil Replacements	Sustainable Feeds	Novel Ingredients	Larval & Nursery Feeds	Feed Enzymes
Production Technology	Offshore and Industrialisation	Hatchery Technology	Real Time Monitoring/ Big Data	Feed management	Post-Harvest Processing
Markets	Market and product developments, generic marketing, certifications, branding, food safety etc				
Company/Product News	News on activities at international, regional and local conferences and trade shows				
More information. www.aquaasiapac.com; Email us for advertising/article contributions and guidelines					

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Email: worldaqua@was.org | www.was.org

India is the second largest producer of aquatic animals through farming and freshwater fish dominate this production. Carps and Pangasius are the top species. Aqua farmers are now diversifying into more species and the country is witnessing changes in the way fish are farmed.

The Society of Aquaculture Professionals (SAP), established by a group of likeminded people for knowledge sharing and development advocacy in aquaculture has its flagship biennial event AQUA INDIA, the go to event for all involved in shrimp farming.

SAP is now unveiling **FISH INDIA,** a platform to understand recent trends, innovations, potential, issues, market updates and professional networking in fish farming. FISH INDIA 2023 is for progressive farmers, feed millers, hatchery owners, technicians, consultants, processors, scientists, and educators to come together, exchange knowledge and network.

FISH India 2023 will be held on February 24- 25 in Vijiyawada. More information: www.aquaprofessional.org

2023

January 30-February 3
32 Annual Practical Short Course on Feeds & Pet Food Extrusion
Texas A&M, USA
www.teesedge.tamu.edu/online/extrusion

February 23 - 26
Aquaculture America 2023
New Orleans, USA
www.was.org

February 24-25
Fish India 2023
Vijayawada
www.aquaprofessional.org

March 8-10
VIV Asia 2023
Bangkok, Thailand
www. vivasia.nl

April 12-14
Vietshrimp Aquaculture International Fair
Can Tho, Vietnam
https://vietshrimp.net

April 18 - 21
Latin American & Caribbean Aquaculture 2023
Panama City, Panama
www.was.org

April 21-22
RASTECH 2023
Florida, USA
www.ras-tec.com

April 25-27
Seafood Expo Global/Seafood Processing Global
Barcelona, Spain
www.seafoodexpo.com/global

May 29 – June 1
World Aquaculture 2023 Darwin, Northern Territories, Australia
www.was.org

August 16-17
TARS 2023 - Shrimp Aquaculture, Bali, Indonesia
www.tarsaquaculture.com

August 25-27
VIETFISH 2023
Ho Chi Minh City
www. vietfish.com.vn/en

August 31- September 2
Taiwan International Ocean and Fisheries Show (TIOFIS 2023)
Taipei
www.taiwanfishery.com.tw

September 5-7
Global Shrimp Forum
Utrecht, The Netherlands
www.shrimp-forum.com/

September 18–20,
Aquaculture Europe 2023,
Vienna, Austria
www.aquaeas.org

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Solver

Eco-safe feed for shrimp

***Cost-efficient feed** with **essential protein level** required for **sufficient growth** in shrimp*

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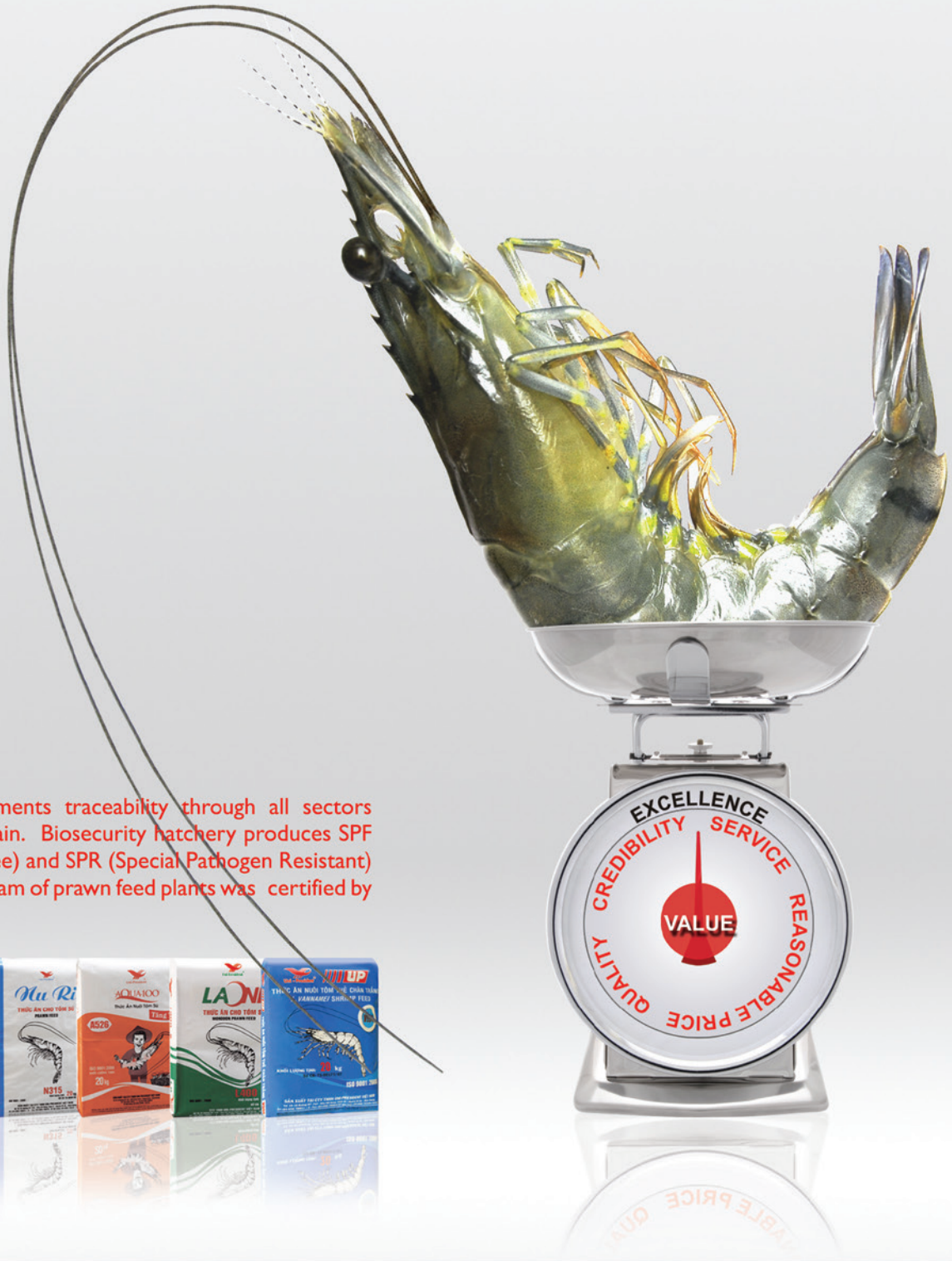

Uni-President implements traceability through all sectors along with supply chain. Biosecurity hatchery produces SPF (Special Pathogen Free) and SPR (Special Pathogen Resistant) larvae. Quality program of prawn feed plants was certified by ISO 22000 & HACCP.

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