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Editor/Publisher
Zuridah Merican, PhD
Tel: +60122053130
Email: zuridah@aquaasiapac.com

Editorial Coordination
Corporate Media Services P L
Tel: +65 6327 8825/6327 8824
Fax: +65 6223 7314
Email: irene@corpmediapl.com
Web: www.corpmediapl.com

Design and Layout
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Email: sales@wordsworth.com.sg
Web: www.wordsworth.com.sg

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Web: www.aquaasiapac.com
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Fax: +65 6223 7314

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Zuridah Merican

A market pull for sustainable feeds?

Aquaculture is in the business of producing seafood protein for the world hence world demand should influence aquaculture production and the supply chain. The past 27 months has been anything but business as usual. Every time we coin the new normal, it is up-ended by another high impact event. Covid-19, subsequent supply chain disruptions, Ukraine and inflation have caused upheaval in the European seafood marketplace, paraphrased from Auden Lem of FAO at the Seafood Expo Global (SEG) in Barcelona, April 26-28. There has been an overall slowdown in economic growth and the resulting effect felt in the first quarter of 2022. Purchasing power has fallen and with it, consumption because of the rise in the cost of food. Composite seafood prices were up nearly 5% in February compared to the same period last year. However, the prognosis is not necessarily bad or similar across the board. Seafood, being a higher priced protein and an attractive item on the menu does not seem to suffer in the food service segment as it appeals to the economically better off. A case in point is that Norway just reported the best April exports of fisheries and aquaculture products. Farmed salmon contributed 82,500 tonnes, worth NOK 8.1billion (USD0.81 billion), a 3% fall in volume but jump of 43% in value.

Another takeaway from SEG is the increasing interest in the upstream segment of the supply chain to produce sustainable aquaculture products. Concurrent conferences highlighted the Environmental, Social and Governance (ESG) risks of feed and ingredients to produce sustainable seafood. This seems to have been driven by the felling of the Amazon Forest to plant soybeans. Ironically, it was only 30 years ago that soybean meal was promoted as a sustainable alternative feed ingredient to complement fishmeal in aquafeeds. Whichever feed ingredient, not all are created equal and this has pushed the Aquaculture Stewardship Council (ASC) to create a proactive industry and identify how to drive change towards a more sustainable food system. This shows that The Aquaculture Roundtable Series 2022 (TARS) has identified the correct challenge and a compelling subject by focusing on aquafeed and the need for a new equilibrium. Aquaculture expansion has increased demand for more feed ingredients to complement fishmeal. The availability of novel ingredients is a boon but again the question to ask is if all are created equal. Winston Churchill said 'Never waste a good crisis' and it is so relevant to the feed industry today when feed prices are on the increase, irrespective of species or geography.

The Global Seafood Alliance offered a good view on revitalising the black tiger shrimp in Bangladesh. Since the early 2000s, Asia has pivoted from black tiger (monodon) to vannamei shrimp such that vannamei comprises over 90% of warmwater shrimp aquaculture today. Bangladesh has always remained loyal to the black tiger which it calls big prawn, even though the country experienced a negative perception of antibiotic residue through no fault of the country or the farmers.

Again, this shows the significant weakness of Asian aquaculture in general whether black tiger from Bangladesh or pangasius from Vietnam. Asia is either not good at defending itself in the marketplace or quick enough to respond to bad publicity. Neither is it capable of generic marketing to brand the product. The minimum requirement today would be for the industry on a country level to set aside competitive differences and work together proactively to promote the product – imagine branding Bangladesh Black Tiger! *Penaeus monodon* is a species which has no competition from Latin America and there is an opportunity to take advantage of this product segmentation.

Asia Research and Engagement (ARE) conducted a study showing only 16% of Asia's biggest companies include responsible protein sourcing policies as part of their ESG disclosure, a gap that undermines their climate, deforestation and sustainable development goals. There has been no specific data so far for the seafood protein industry, but the seeds have been planted for a market pull for sustainable feeds and it will be a matter of time before the seafood market demands this and we, in Asia should board this train now.

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

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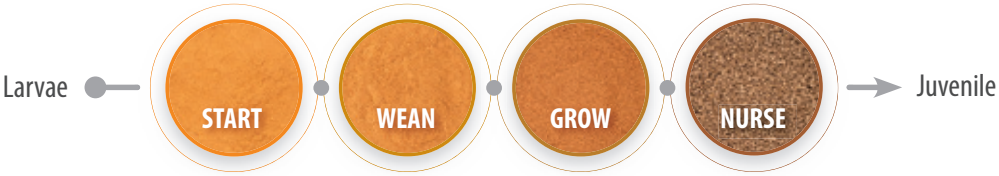

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Sustainable Feeds – working with markets

A clear trend at this year's Seafood Expo Global (SEG), held from April 26 to 28 in Barcelona, is how markets are tracking use of sustainable ingredients in aquaculture production.

At the Global Salmon Initiative (GSI) panel session. Aquaculture already has a low carbon footprint, but needs improvements to maintain its position as a climate-friendly food production option.

Asian feed producers have conflicting interpretations on what sustainability means for them. Sustainable feed is generally interpreted as one with a low carbon footprint, includes sustainable raw materials and energy saving feed processing methods to produce safe and environmentally friendly and healthy feed.

Some producers think that the timing is not yet right to consider feed sustainability and that its aquafeed industry is not well developed enough to include the need for feed sustainability. What is more important is having a competitive edge. If sustainable feed ingredients mean more expensive products, it is not a win-win situation amidst a competitive environment and current situation with high feed raw material costs. While industry leaders encourage feed producers to use renewable protein resources, feed producers favour the need for feed quality and consistency while protecting the ecosystem by adopting lesser polluting processing methods. A commercial Future of Fish Feed (F3) feed is available in Vietnam but needs a market pull for adoption by farmers.

At SEG, three separate sessions focussed on sustainable feeds. The panel on how to measure and reduce carbon emissions in tropical aquaculture addressed the issues brought up from the IDH aquaculture working group focussing on environmental footprint of aquaculture of the whole value chain, especially on aquafeed.

IDH facilitates a pre-competitive Aquaculture Working Group to improve the methodologies for measuring and reducing the environmental footprint of aquaculture. Methodologies on greenhouse gas (GHG) emission, water use and eutrophication are being developed; currently members involved in methodology development are from companies in the shrimp, tilapia and pangasius value chain.

The panel discussed how carbon along their supply chains can be measured, where carbon hotspots are in tropical aquaculture supply chains, and how the footprint of aquaculture products can be evaluated. Some points raised included the use of soy in aquafeed; carbon footprint of fishmeal and fish oil; and how to get feed producers, feed suppliers and producers to the table.

The Global Salmon Initiative (GSI) panel stressed that, in addition to setting climate targets, it must ensure that the targets are achievable. There are lessons here to learn from salmon aquaculture. The industry already has a low carbon footprint, but improvements are still needed to maintain its position as a climate friendly option. Sophie Ryan, CEO, GSI, said that despite companies with GSI being fierce competitors, her job is to bring competitors into one group, working together for the benefit of the whole industry. Common metrics are needed.

Carlos Diaz, CEO, BioMar said that it sets science-based and realistic targets. By 2030, 50% of raw materials will be circular and restorative ingredients. "Although Grieg Seafood is already far ahead, it still needs to improve," said Kristina Furnes, Group Communication Manager. Across species, Diaz said improvements are happening fast, such as in marine fish and marine shrimp and across countries, in China and in Vietnam, the latter with ASC certification.

GSI has been working in partnership with WWF to establish an accounting framework for greenhouse gas emissions for the farmed salmon sector, from feed to consumer. Some 60-70% of farm gate emissions are from feed and if the feed includes soy produced from deforestation and conversion in Brazil, then it could add more emissions to the embedded carbon in salmon (WWF-US). Cont'd on page 6.

Partnership for sustainable black tiger shrimp in Bangladesh

Global Seafood Alliance (GSA) and the Bangladesh Shrimp and Fish Foundation (BSFF) have joined forces on a World Bank-funded project of the Bangladesh Department of Fisheries to uplift the country's small-scale shrimp farmers and revitalise black tiger shrimp (*Penaeus monodon*) farming. This partnership was announced in August 2021.

On April 27, during the Seafood Expo Global (SEG) held in Barcelona, Spain, Dr George Chamberlain, GSA, assembled buyers, NGOs and stakeholders to a dialogue on marketing sustainable black tiger shrimp from Bangladesh.

Bangladesh exports 85% of its shrimp to Europe. According to Bangladesh's Export Promotion Bureau (EPB), exports of black tiger shrimp in six months of the 2021-2022 fiscal year (July-December 2021) were valued at USD268.95 million (seafoodsource.com), an increase of 38.2% from USD 194.58 million in the same period in 2020.

The black tiger shrimp is a major export commodity for Bangladesh. The species is farmed at very low density without supplemental feed and can easily reach 300g. Production is from small scale farms harvesting small quantities, middlemen aggregate production from multiple farms and transport the collective harvest to processors, often with delayed delivery and compromised quality.

Chamberlain said that the opportunity is to form clusters of farms, sell directly to processors, produce premium quality, return a fair value to farmers and help them increase yields using improved practices. This is however an enormous challenge because farms are small, often one hectare in size. Farms cover a total area of 250,000ha. The challenge is also how to group, train, track, improve and reward such large numbers of small farms in such remote areas. From a social aspect, there is the opportunity to lift farmers out of poverty by producing distinctive size, quality and brand such as "Premium Natural Tiger Shrimp."

The project will also encourage adoption of third-party certification to ensure compliance with international standards and strict product quality grades to incentivise production of Grade A product. This approach will yield large, naturally pigmented black tiger shrimp with excellent quality, international certification and low carbon footprint. These attributes are expected to generate more consumer confidence and satisfaction, premium prices in the international markets, attractive returns to small-scale farmers and sustainable development of the sector. However, the enormous number of farms will need AIPs (aquaculture improvement programs).

Subsequent steps will include improved farm productivity with high quality post larvae produced from SPF broodstock, supplemental feeds from low-carbon-footprint ingredients and educational programs in collaboration with The Center for Responsible Seafood (TCRS). The successful implementation of this project will benefit small-scale black tiger shrimp farms in other producing countries and to help revitalise the black tiger shrimp market worldwide.

During this meeting, NGOs and marketeers shared views on improving productivity and net incomes of black tiger shrimp farmers in Bangladesh. Mahbubul Haque, Director General, Department of Fisheries, said that each cluster comprises 25 farms and to date 300 clusters have been formed. Productivity can double with deeper ponds and by July, the first crop will be ready to market.

On sourcing shrimp from small scale farmers, Dominique Gautier, Sea Fresh Group listed three points; the need for an authority to organise the group and control production practices; an agreed code of management practices and compliance to enter the group; and control systems to document compliance. He emphasised that management practices include traceability, responsible sources of post larvae, use of chemicals, impact on water resources, pathogen control, responsible working conditions and many more. Some of these are usually handled by processors. Processors can access markets without third party certification, but this depends on the internal control systems. On certification, Gautier said that local buyers and processors need to play key roles in ensuring food safety, from harvest to processing as well as with funding.

Chamberlain explored as an example the marketing of sustainable black tiger shrimp by Unima in Madagascar into the premium markets in Europe. One concern raised by a UK based buyer is how to pitch the black tiger and against vannamei as the younger generation is very familiar with the latter. If black tiger is bigger and better, how do we sell this story. One option is working with chefs to create a story. A local company called for repositioning the black tiger which requires changing the perception of global consumers through rebranding, reassurance and coordinated marketing campaign (aci-bd.com). The issue of image building was raised and ultimately, Bangladesh like other Asia seafood producers, needs to be quick to counter adverse information in social media and online articles and work towards generic marketing for its black tiger shrimp.

More Sustainable Feed

More Sustainable Feed is a Grieg Seafood and WWF-US project to evaluate environmental, social and governance (ESG) risk in salmon feed ingredients it uses. The approach is to analyse both the feed ingredients and the suppliers of those ingredients. The goal is to reduce ESG risks to the company from purchased feed; it also takes into consideration wherever possible of the economic incentives for greater ESG risk reduction. To mitigate the risk of overfishing, the company uses less marine ingredients in its salmon feed. Unfortunately, some of the alternatives used, like Brazilian soy, were later linked to new issues of concern, such as deforestation and conversion.

The outcome of this work will help to enhance Greg Seafood' feed strategy and its approach to novel feed ingredients. While Grieg Seafood is undertaking this work for its own purpose, findings will be available to other salmon aquaculture producers plus downstream buyers, investors and even consumers and producers of other animal proteins, including other aquaculture species.

Feed ingredient liabilities are of great concern to producers since the buyers, financiers and even end consumers are interested in the full supply chain risk reduction. Unless farms are vertically integrated with feed production, most animal protein companies will not know the origin of all the ingredients that are in their feed as well as how and where those ingredients are produced. In animal protein production, 100 or even more ingredients are in the feed and it would be difficult to list all of them and their origin on the package. In shrimp aquaculture feed companies do not provide information, beyond total protein.

Grieg Seafood identified WWF-US office as the core partner in the project for the design of the overall assessment. During the discussion at SEG, on the ESG risks in feed ingredient supply chains, the Grieg Seafood and WWF-US teams outlined the scenario today and that of the future. Many ingredients are at risk -certified (fishmeal and soy). Novel ingredients have embedded ESG issues when they scale up. In general, industry is too reactive and needs to be more proactive. Together, industry needs to identify and mitigate ESG, drive change to be a sustainable food system; and work towards a 100% traceable and transparent supply chain.

On some key takeways, they said, "Feed is a black box. It is far from transparent and traceable. Often it is only traceable a few steps down the supply chain. There are many risks that we are not aware of. Pre-competitive collaboration to address issues concerning animal protein production and value chains is needed to achieve change at scale effectively. A proprietary approach is not the way forward. Each company cannot have their own ESG system or use different life cycle assessments (LCAs). Common definitions and methodologies are necessary. We should aim to either remove the worst performers within each ingredient from our supply chain and incentivise farmers to become better."

Expansion and acquisition of feedmill in South Mindanao

In the Philippines, **ADM** a global leader in animal nutrition, has acquired South Sunrays Milling Corporation (SSMC) feed mill in Polomolok, South Cotabato, Mindanao. The addition is a step forward in providing a wide range of leading-edge products to meet Asia's demand for innovative and high-quality products in the animal nutrition market.

"Globally, ADM is expanding its ability to meet growing customer demand for high-quality, responsibly-produced animal nutrition products, and we look forward to bringing our expertise and production capabilities closer to even more customers in the Philippines," said Gerald Wilflingseder, President, Animal Nutrition, Asia Pacific, ADM. "This addition increases our regional production capacity, enabling us to enhance our wide range of leading-edge solutions to better support our customers' dynamic needs in a timely manner, while providing further opportunities to offer new product solutions in the Philippines and across the region."

The South Cotabato mill, along with existing ADM feed production facilities in Cebu and Bulacan, support customer growth in the region with a wide range of leading-edge pet food, complete feed, aquaculture and premix solutions. Further, the investment will support economic development through the creation of more than 100 new jobs in the region.

"We are excited to combine our global expertise with deep local insights to unlock greater value for our customers in the Philippines and across the region," said Lorenzo Mapua, managing director, Animal Nutrition, Philippines, at ADM. "This acquisition will allow us to offer a wide range of high-quality feed products for swine, poultry and aqua for both backyard and commercial farm segments with our recognised brands such as Ultrapak, Evialis and Ocialis."

SSMC started the feeds tolling business in South Cotabato in April 2017. After three years, SSMC expanded its second feed mill to produce quality feeds for aquaculture, petfoods and extruded raw materials like full-fat soya and other raw materials. One of their milestones includes venturing into shrimp farming in Sarangani province, under a new corporation, South Sunrays Aqua Ventures Corporation.

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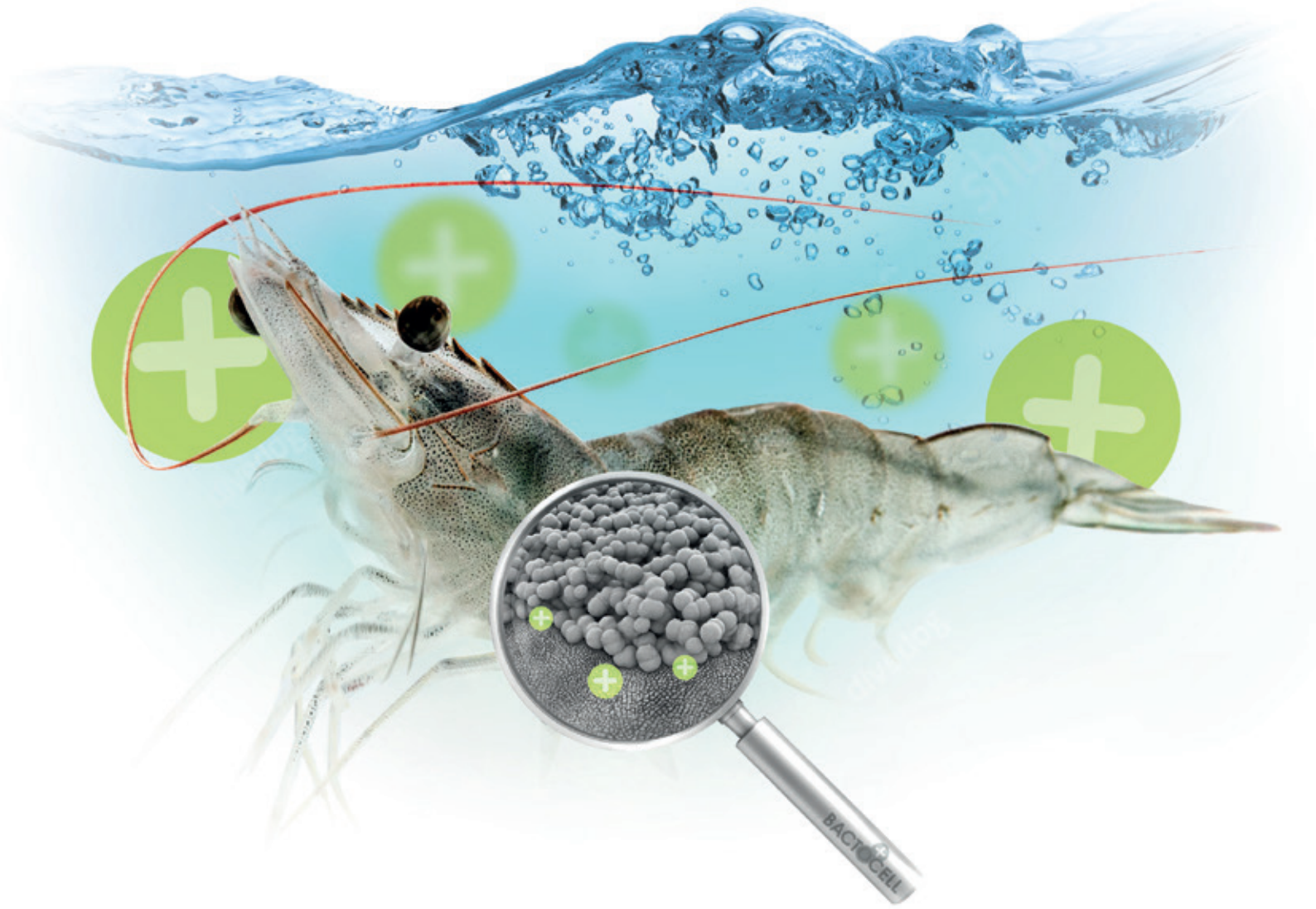

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Some important statistical analyses for shrimp farm management

Without any bias, both variance component analysis and coefficient of variation are simple statistical methods to measure shrimp farm and production staff performance.

By Dean M. Akiyama

The specifications for outdoor ponds have not changed significantly in over 20 years. The same ponds, given the farm infrastructure, are being used to produce shrimp with modifications in production technology used. I believe that farm infrastructure and farm management are the major limitations to future production. Given farm limitations, there needs to be more focus on production efficiency and consistency to achieve profitability.

Farm managers need an unbiased measure for farm and technician performance. Pond profit-loss is the most critical for shrimp production sustainability. However, profit-loss is highly dependent on shrimp farm price, which is market dependent because of global demand for shrimp. If shrimp farm production is efficient and consistent, the production technology of the farm is managed well and will be financially better, regardless of the farm price of shrimp.

Variance components analysis

Good farm management and control are vital to the success of shrimp pond production. This was clearly shown (Table 1) in an extensive pond performance evaluation in Indonesia, where daily pond management, post larvae quality and feed were analysed for their influence on pond production parameters. Variance components analysis (VCA) assesses the amount of variation in a parameter (pond production) that is affected by other variables (farm management, water quality and, feed). The analysis estimates the amount of variation contributed by each variable. The sum of all variance components equals the total variation (100%).

These pond production parameters include harvested biomass (tonnes/ha), mean body weight (g), survival rate and feed conversion ratio (FCR). Over 3 years, these analyses were done for 32,000 ponds. All ponds were HDPE lined rectangular ponds of 2,500m^2, stocked at 70-80 PL/m^2 with 30 HP/ha of paddlewheel aeration. The daily farm management parameters included water quality variables (dissolved oxygen, temperature, pH fluctuation, salinity, transparency, and water colour), feed management variables (feeding/day, time of feeding, and daily feed quantity), and animal health and biosecurity variables (total *Vibrio* count, PCR virus check, parasites, gill and carapace examination).

Post larvae quality was determined by a composite score per batch of post larvae harvested. The scoring consisted of the following criteria: necrosis, size variation, deformities, post larvae activity level, total *Vibrio* count, luminescent bacteria, gut-muscle ratio, ectoparasites, chromatophores, muscle clarity, and stress tests. There were established quality parameters for post larvae acceptance by pond production managers. All broodstock and post larvae (PL3 and PL8) in this study were PCR tested for infectious hypothermal and hematopoietic necrosis virus (IHHNV), Taura syndrome virus (TSV) and white spot syndrome virus (WSSV). All post larvae were virus negative.

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Feed quality was determined by the formulations which, in general, were changed monthly. However, pond production managers established quality parameters for feed acceptance which included proximate analyses values, water stability, uniform size, uniform colour and dust level per bag.

Variance Component	Biomass (g)	MBW (g)	SR (%)	FCR
Feed	15	22	16	10
Post larvae quality	19	23	24	15
Pond management	66	55	60	75
MBW=mean body weight; SR=survival rate and FCR =feed conversion rate.				

Table 1. Results for Variation Component Analyses for harvest shrimp production performance

Pond management

Pond management component was expected to be high in an integrated shrimp farming system. This is because when post larvae quality was below acceptance standards, the post larvae were flushed out. Furthermore, when feed quality was below expected standards, the feed was rejected and not released to the market. These management concepts gave the highest probability for good shrimp pond production.

The pond management had 66% influence on biomass (Table 1). Biomass is (stocking density x SR x (days of culture x ADG) where SR is survival rate (%) and ADG is average daily growth (g). Biomass is not an independent variable but a composite of variables and had the most influence on the financial profitability of the pond.

Pond management had 75% influence on FCR (Table 1). To achieve good FCRs, it was more critical to feed the correct daily amount and properly adjust the feeding rate required by the shrimp compared to only feed quality. Shrimp appetite can change drastically with water temperature and dissolved oxygen (DO) levels. Shrimp appetite is low in the morning because of low water temperatures and DO levels. As the temperature increases during the day, shrimp appetite will increase concurrently.

"A more realistic VCA would be pond management (50-70%), feed quality (15-25%) and post larvae quality (15-25%) for shrimp production without the integration system."

Shrimp are poikilotherms (cold blooded animals), therefore, the water temperature directly affects shrimp metabolism and appetite. For each degree (°C) reduction in water temperature, shrimp metabolism will be reduced by 8-10%, which directly affects shrimp appetite. Rain affects the pond water temperature, salinity and pH. All these daily fluctuating water quality parameters affect shrimp metabolism and appetite. It is normal to have a 10-20% difference in daily feed consumption. The exact feed quantity per time and/or per day is the best guess estimation. Thus, feeding tables and fixed feeding rates are only guidelines for actual daily shrimp feed consumption.

As an independent shrimp producer, where post larvae and feeds are bought from suppliers, the post larvae quality and feed quality should be less stable and less controlled. A more realistic VCA would be pond management (50-70%), feed quality (15-25%), and post larvae quality (15-25%).

Coefficient of variation

The coefficient of variation (CV) is a statistical measure of the dispersion of data points around the mean. CV represents the ratio of the standard deviation to the mean, and it is a useful statistical tool for comparing the degree of variation from a data set. The CV is useful for estimating risk. The higher the CV value, the less predictable the results, and the higher the risk.

CV of production variables (production level, ADG, FCR, and SR) can be used as a management tool to monitor shrimp farm management systems. The CV values can be used to monitor consistency in the production system and management by staff. If production levels are consistent with low CV, the staff management, production facilities (pond design, incoming water, level of aeration, etc.), feeds as well as post larvae quality are good and well controlled. If the CV is high, there will be some parameters that can be improved within the farming system.

	Pond production (tonnes/ha)		
	Farm A	Farm B	Farm C
Pond 1	2	3	4.2
Pond 2	3	3.5	4.4
Pond 3	4	4	4.6
Pond 4	5	4.5	4.8
Pond 5	5	5.5	5.2
Pond 6	6	6	5.4
Pond 7	7	6.5	5.6
Pond 8	8	7	5.8
Average	5	5	5
Coefficient of variation (CV)	0.4	0.29	0.12

Table 2. Example of farm production (harvest/cycle/farm) coefficient of variation of 8 ponds.

All farms (A, B, C) average 5 tonnes/ha production level (Table 2). However, Farm C with a CV of 0.12 for production is the best managed farm with the most control of all production parameters. Farm C's production is more predictable and most profitable. In general, it has been observed globally in shrimp farms that CVs of less than 0.15 are less than 10% of the total farms. A greater than 0.40 CV exceeds 50% of the total farms. Below are guidelines for farm managers and owners to evaluate farm performance, where improvement should be applied and how to proceed for the next farming cycle.

- If CVs are higher than 40%, the stocking densities and production level targets should be reduced.
- If CVs are between 15-30%, the farm management is stable and should maintain stocking densities and production level targets.
- If CVs are lower than 15%, the farm is very well managed. Then the farm should consider increasing stocking density and production targets.

These guidelines should be evaluated with consideration given to pond profitability. Profitability conditions are constantly changing as well as different, influenced by market demand and country/region situations.

"..regardless of the production level, analysing CV for FCR can help to determine if feed management is properly carried out and/or if the feeding system is acceptable."

Staff performance

CV analyses can also measure individual staff performance if he/she is directly responsible for several ponds. The production level of every pond within the staff's responsibility can be analysed for production consistency. This analysis can be done on a seasonal basis and/or over several harvest cycles. The greater the number of ponds being analysed, the better the accuracy of analyses. Or regardless of the production level, analysing CV for FCR can help to determine if feed management is properly carried out and/or if the feeding system is acceptable. When mortalities occur early in the production cycle, feeding can still be managed for low FCR. The FCR increases considerably only with mortalities in the last weeks of the production cycle, when larger shrimp are dying.

Feed distribution in a high aeration, high stocking density pond.

Summary

We know that the key to successful shrimp production is the motivation and dedication of farm staff at the pond level. It is critical that all implement and complete assignments correctly and immediately when required. The variance components analyses and coefficient of variation analyses are simple statistical methods to measure shrimp farm and production staff performance without any bias.

Dean M. Akiyama, PhD. is an Aquaculture Advisor, based in Jakarta, Indonesia.
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MiXscience Asia
Số 91-93 đư ờng số 5, Phường An Phú, Thành phố Thủ Đ ức, Thành phố Hồ Chí Minh, Việt Nam

Mail : maxime.hugonin@mixscience.eu
thomas.pierrot@mixscience.eu

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A focus on perpetual improvement: Why the marine ingredients sector is embracing lifecycle assessment sciences

By Brett D. Glencross

The sustainability of growth

Over the past 20 years we have seen unprecedented growth in the aquaculture sector and predictions are for this to continue. In 2020 global aquaculture production was reported at around 63 million tonnes per annum, using about 52 million tonnes of feed (Figure 1). Based on the Food and Agriculture Organisation's (FAO) estimates for aquaculture production up to 2050, we may see aquaculture production more than double and reach yields of 140 million tonnes. However, this will also mean that feed production needs to at least double to over 100 million tonnes during this time. But where will we get the feed ingredients to sustain that and just as importantly, how can we ensure the sustainability of that?

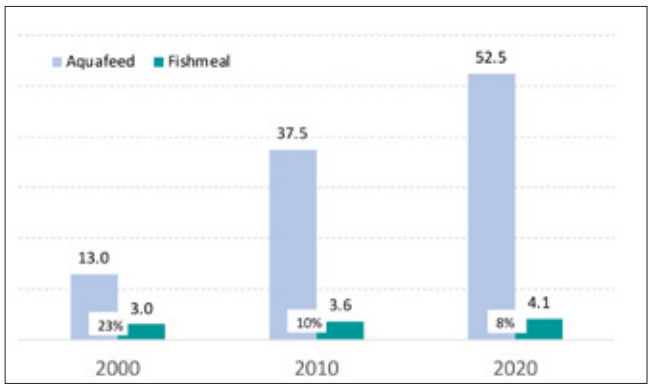

Figure 1. Global aquafeed production and fishmeal use (tonnes and percent of total feed) by aquaculture from 2000 to 2020. Source: IFFO, 2022.

What does "sustainability" mean?

That term "sustainability" is one that is widely used these days. The original Brundtland definition was something like "sustainable development is that which meets the needs of the present without compromising the ability of future generations to meet their own needs." It did not take long for us to realise that there was little in food production that met those criteria. An alternative approach was proposed by Herman E. Daly (former Chief Economist for the World Bank), who proposed three operational rules defining the conditions for ecological sustainability:

- Renewable resources such as fish, soil and groundwater must be used no faster than the rate at which they regenerate.
- Non-renewable resources such as minerals and fossil fuels must be used no faster than renewable substitutes for them can be put into place.
- Pollution and wastes must be emitted no faster than natural systems can absorb them, recycle them, or render them harmless.

Notably, that first condition for use of renewable resources strikes a clear chord with the marine ingredients sector. Especially in the present day, when nearly all the major forage fisheries are independently quota regulated and increasingly independently certified as well. However, the further you dig into the sustainability story, it becomes apparent that there are several different approaches. A simple search on the internet provides an extensive list of various alternatives [wikipedia.org/wiki/Sustainability_metrics_and_indices]. This has become part of the issue in understanding the requirements of sustainable development and the various metrics that are used. So, the other question to ask is, why do we need metrics?

You cannot manage, what you cannot measure!

Metrics, irrespective of what they are used for, are simply a basis for establishing relevant goals and measuring progress against them. This allows then, for you to demonstrate impact, effectiveness, and value against those goals. In effect, you cannot manage something if you cannot measure it. The process of establishing relevant metrics is almost a field in itself. However, most of us will have heard of SMART (Specific, Measurable, Attainable, Relevant, Time bound) approaches to performance management and establishing metrics for sustainability criteria is no different in this regard.

In pursuit of sustainability in food production systems around the world, various metrics have been proposed; however, the one gaining most favour and utility over the past decade has been that of Life Cycle Assessment (LCA). An LCA approach to sustainable development aims to compare the full range of environmental effects assignable to defined products and services by quantifying all the inputs and outputs associated with various material and energy flows and assessing how these flows affect the environment (Figure 2).

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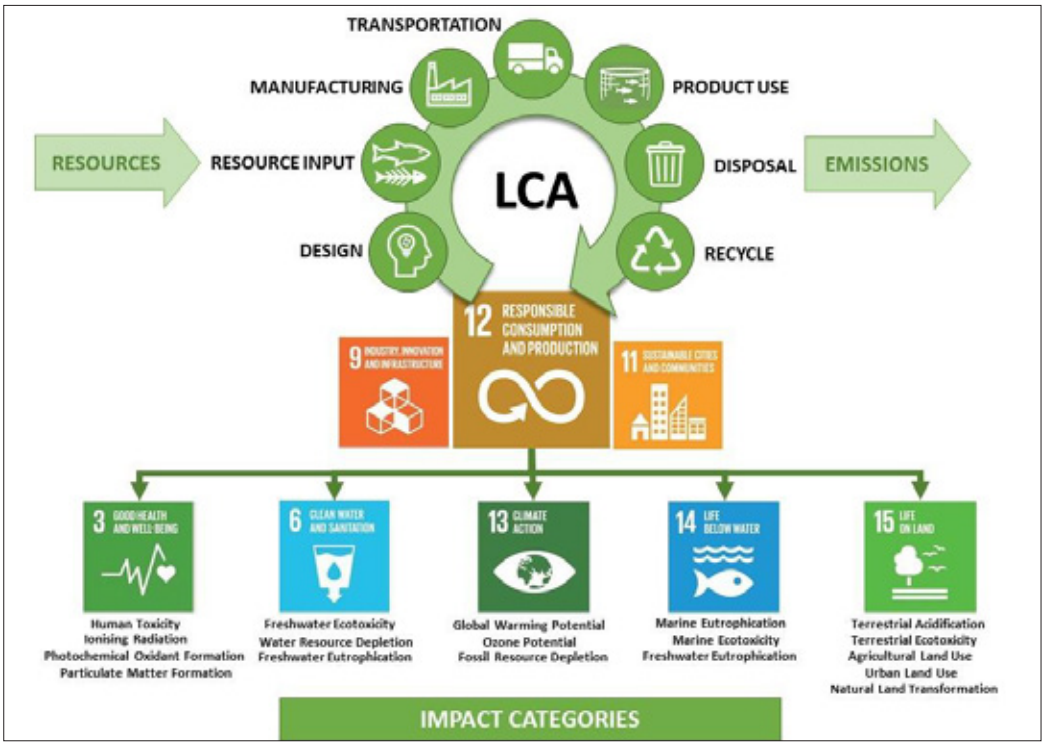

Figure 2. Linkage between LCA analysis, Sustainable Development Goals and LCA Impact Categories.

To achieve this, the compilation of an inventory of relevant energy and material inputs and environmental releases is required. This then allows an evaluation of the potential environmental impacts associated with each of the identified inputs and releases. Part of this process is the characterisation of emissions, whereby different emissions are standardised into equivalents. For example, in terms of global warming potential (GWP), which is measured in carbon dioxide (CO_2) equivalents, one unit of CO_2 = 1 equivalent, whereas methane (CH_4) has 25x the CO_2 equivalent in terms of GWP.

Another of the important considerations of LCA is the observation that environmental impacts do not just occur on the unit of production. Impacts can occur throughout the value-chain from raw material extraction (capture), to processing, distribution, consumption and of course at the point of waste disposal (or recycling). Each of these stages requires land, water, raw materials, and energy, and each can contribute to emissions of some kind or other. Another aspect to the LCA story, is that it is not constrained to just carbon footprint, with up to 18 different environmental impacts now being assessable (Table 1).

Importantly, LCA is increasingly seen as the "mainstream" way to establish environmental credentials. The process of undertaking an LCA analysis though requires lots of planning and data. How you plan and how you collect the data can have important effects on the interpretation. Because of these constraints, there have been various attempts to set some standards on this. The International Standardisation Organisation (ISO) initiated this (ISO 14040 series); the European Union has also taken a lead with the Product Environmental Footprint Categorisation Rules (PEFCR) approach and more recently the Global Feed Lifecyle-Assessment Institute (GFLI) was established to be an independent repository with freely available database and tools.

No.	Impact Category	Acronym	Equivalents
1	Global Warming Potential	GWP	kg CO_2 eq
2	Ozone Depletion	OD	kg CFC-11 eq
3	Terrestrial Acidification	TA	kg SO_2 eq
4	Freshwater Eutrophication	FE	kg P eq
5	Marine Eutrophication	MEu	kg N eq
6	Human Toxicity	HT	kg 1,4-DB eq
7	Photochemical Oxidant Formation	POF	kg NMVOC
8	Particulate Matter Formation	PMF	kg PM10 eq
9	Terrestrial Ecotoxicity	TE	kg 1,4-DB eq
10	Freshwater Ecotoxicity	FE-Tox	kg 1,4-DB eq
11	Marine Ecotoxicity	MEc	kg 1,4-DB eq
12	Ionising Radiation	IR	kg U235 eq
13	Agricultural Land Occupation	ALO	m^2 area
14	Urban Land Occupation	ULO	m^2 area
15	Natural Land Transformation	NLT	m^2 area
16	Water Resource Depletion	WD	m^3
17	Metal Resource Depletion	MD	kg Fe eq
18	Fossil Resource Depletion	FD	kg Oil eq

Table 1. Impact categories associated with the ReCiPe Midpoint Criteria

Equitable comparisons

It has become clear in recent years that aquaculture is making a strategic use of marine ingredients, leveraging the high-nutrient density and palatability stimulating characteristics of those ingredients to underpin the global production of 52 million tonnes of feed. However, finding additional ingredients to provide bulk nutrients into the future is a clear and growing need.

From the data in Figure 1, we can clearly see that more than 90% of the ingredients used are NOT of marine

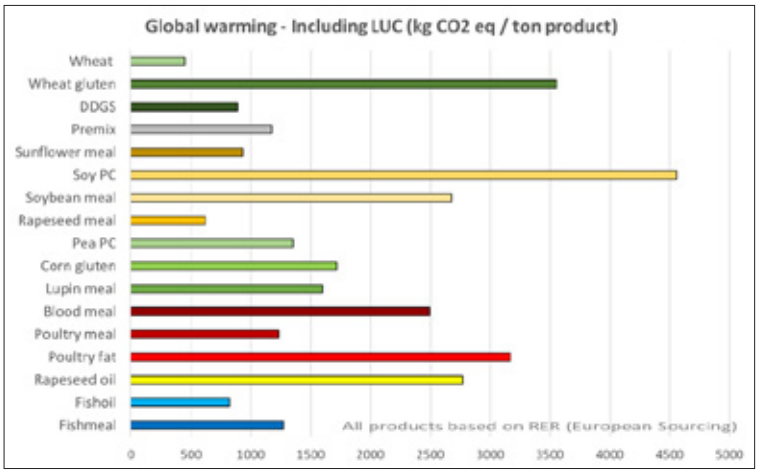

Figure 3. Carbon footprint (Global Warming Potential) of fishmeal, fish oil and a range of plant proteins and oils. Data are based on European region (RER) economic allocation basis values from the GFLI ReCiPe Database. Data from GFLI 2022.

origin, and that the total volume of marine ingredient use in the sector has increased only marginally over the past 20 years. Indeed, an analysis of feed formulations across a range of species shows that plant proteins and oils are now providing the bulk of the nutrients in most aquaculture feeds, and this is likely to remain the case for some time. However, recent studies have shown that this use of plant resources worsens the environmental footprint of aquaculture more than if we had stayed with the use of marine ingredients.

Underpinning that assertion about what is more sustainable has been the advent of LCA sciences, which allow us to look more holistically at the sustainability story of everything we use and on a basis of a more equitable comparison. For example, simplistic fish in: fish out (FIFO) ratios can hardly be applied for cattle production, and no one seems to have come up with a grain in: cow out (GICO) ratio to allow some kind of equity in the story. However, use of LCA is widely accepted and the environmental impacts it includes are applicable across most food production sectors.

So, when we examine things using an LCA approach what are our most sustainable options? Among the various alternative proteins and oils now being used and/or considered, we find that their production typically has a high demand for energy, a higher CO_2 footprint and uses substantially more land and freshwater, than marine ingredients (Figure 3). So even though they contribute desperately needed new nutrients into our feed-chain, this is not without some environmental cost. Maybe something we need to further consider here is the carbon cost of an ingredient as an additional use criterion in feed formulation, and I note that several feed manufacturers are now publicly reporting their abilities to do as such. Notably, such a move would transfer additional cost to the higher carbon footprint ingredients, while at the same time encouraging the use of those ingredients with a low carbon footprint and at the same time monetising that point-of-difference to further encourage production of the low carbon footprint ingredients. Irrespective of the strategy we adopt, this whole issue of sustainability and carbon footprint is going to become increasingly highlighted and eventually the carbon-cost will become part of the cost we all pay.

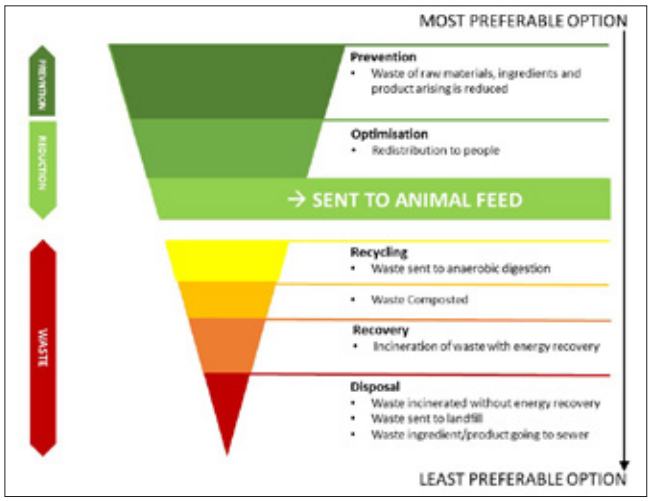

Figure 4. Food/Feed Resource Use Hierarchy.

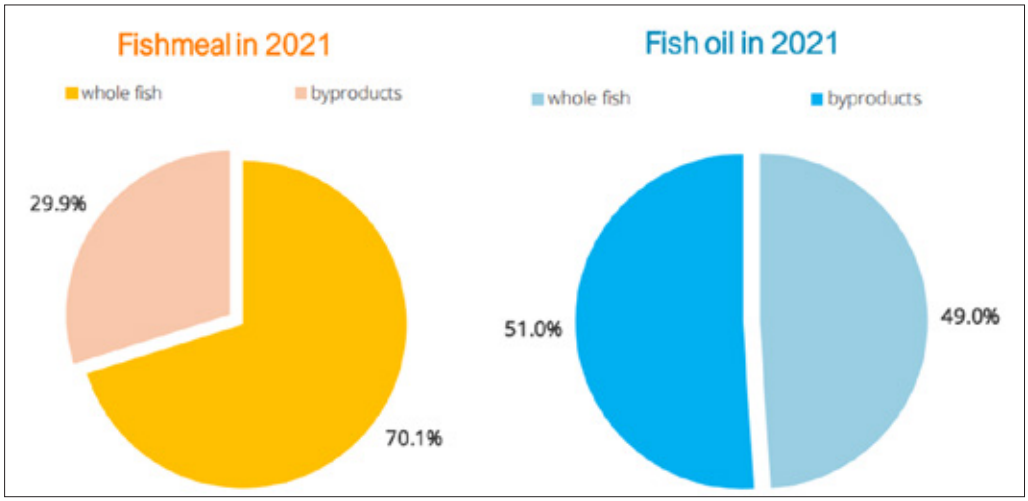

Figure 5. Production in 2021 of fishmeal and fish oil from whole-fish and byproducts. Data from IFFO 2022.

Responding to the growing demand for protein, there has been a boom in new enterprises promoting insects, single-cell proteins, and microalgae, among others but notably the only circular ingredients with any scale (pardon the pun) are the use of fishmeal and oil from trimmings and by-products. In 2021 this sector of the marine ingredients industry produced close to 2 million tonnes, clearly putting it in a different league to the newer emerging "novel" ingredients sector. In fact, if we combine the low carbon aspect of marine ingredient production with the "circular" protein strategy we take something that has a pretty good environmental footprint already - low CO_2 discharge, low energy use, and little to no reliance land or freshwater, and make it into something super special, an ingredient with superb nutritional properties and an even lower carbon footprint.

No such thing as waste

Circular protein strategies for the feed sector are arguably not a new concept, but more of a resurrection of what historically we always used to do, but perhaps now presented through a different lens of an environmental perspective. Indeed, use of resources as animal feed is seen as one of the preferable options in the food/feed source use hierarchy (Figure 4). With a looming shortage of protein resources, the need for an approach with increasing circularity in resource use, coupled with the application of some new novel tech to supply the bulk nutrients, may be what is required to fill that future gap. However, the challenge here remains as to how we can effectively implement these technologies at a scale to sustain the rate needed to provide those nutrients and to deliver this at a cost-point competitive in the marketplace based on their nutrient density.

When we examine the IFFO 2021 marine ingredient production statistics we note that the production of fishmeal and oil from trimmings and by-products is already at a significant scale and far from what we would call "novel". We now have more than half (51%) of all fish oils (~600,000 tonnes) and almost 30% of all fishmeals (~1.4 million tonnes) coming from various by-product raw material streams (Figure 5). Combined, that is close to one third of all marine ingredients currently produced. While this momentum behind the use of "circular" proteins and lipids is clearly growing, examination of where all this comes from shows aquaculture as now a major player in the provision of fish oils, with both salmon and pangasius sectors being significant contributors. On the fishmeal front, while aquaculture is a comparative minor contributor, we note that by-products from human food fisheries contribute 20% of all production, with most of this coming from various pelagic and demersal fisheries.

Back to the LCA story, the other brilliant part with using by-products is their incredibly low environmental footprint. Most LCA analyses, and especially that in the feed sector is now based on economic allocation, with such allocation methods recommended by PEFCR-Feed and GFLI methodologies. However, the primary catch/production of fish for human consumption means that most of the economic allocation is taken by the food portion, even though that fraction often represents less than 50% of the raw material. This means that the lower-value by-products are attributed an even lower allocation of the environmental footprint. So, materials that are already low CO_2 discharge, low energy use, with little to no reliance on land or freshwater, become even less so.

By embracing an LCA approach to assessing marine ingredient sustainability, the industry will ensure that it remains accountable on a more holistic and widely accepted path forward for environmental footprint assessment moving into the future. By embracing the use of circular protein and oil use, marine ingredients production industry is taking a proactive step to be part of building a waste-free world. Together these elements are all part of the proactive approach by the industry to maintain perpetual improvement. Given the increasing use of LCA sciences provides a clear and structured way to assess sustainability credentials; adding in the growing role of by-product use and its ultra-low footprint, it is all certainly food-for-thought as to why the marine ingredients sector going forward is embracing lifecycle assessment sciences.

Brett D. Glencross, PhD is Technical Director at IFFO, The Marine Ingredients Organisation, London, United Kingdom.
Email: Bglencross@iffo.com

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Charting sustainability in aquaculture

Two company leads speak of the various initiatives that showcase Cargill's committment to make aquaculture better for the world.

Cargill is among the leading aquafeed producers with a strong focus on sustainability. With demand for seafood rising, the company believes that it is essential to meet this need sustainably – by producing seafood in ways that decrease environmental impact while feeding growing populations. For this to happen, supply chains need to be transformed. Cargill works closely with suppliers to grow planet-friendly ingredients and find ways to reuse by-products, like fish trimmings that would normally be discarded, whenever possible. It works closely with farmers to source sustainable ingredients, improve farm productivity and ensure fish welfare.

In 2021, it launched the initiative SeaFurther™ Sustainability to help aquaculture farmers raise more sustainable seafood with less environmental impact. Part of the company's overall carbon commitment, SeaFurther's aim is to reduce the emissions of customers' fish by 30% by 2030 (that is, the CO_2 emissions per kg of harvested biomass).

SeaFurther alone will help save two billion kg of CO_2 by 2030. This program starts with salmon farmers, who are focused on the role they play in ocean stewardship and addressing the sustainability of food systems, especially with relation to climate change. Today, feed represents up to 90% of a salmon's environmental footprint.

In this email interview, **Dave Robb**, SeaFurther™ Sustainability Program Lead - Cargill Animal Nutrition and Health, responds to questions on the above program. Each year, Cargill releases its sustainability report which for aquaculture covers aquafeeds too. **Taylor Voorhees**, Sustainability Lead, Cargill Aqua Nutrition (CQN), gives his views on the sustainability report and comments in general on the company's solutions to increase customers' focus on sustainability.

Dave Robb (left) and Taylor Voorhees at Seafood Expo Global in Barcelona, Spain in April: Defining sustainability as investment for resilience in the long term.

SeaFurther and sustainability reports

AAP: Why is SeaFurther starting with salmon farming?

Dave Robb: Salmon farming is the most developed sector in aquaculture and we saw some of our customers have already developed their own targets for reduction of GHG emissions. But the aquaculture industry needs bold actions to improve its footprint and we see an opportunity in the principles guiding SeaFurther, as they can be applied to any farmed aquaculture species in the future.

We have currently two pilot customers in place and more underway. In the first year, we already unlocked 10-20% GHG reductions for pilot customers and we have defined a path for additional improvements, to be measured via LCA (life cycle assessment), focusing on the carbon emissions throughout the value chain from raw material production and processing, through feed manufacture to fish production.

AAP: Why is it important for Cargill to release an annual sustainability report? Who is demanding this?

Taylor Voorhees: There are two main reasons that Cargill releases an annual sustainability report – this year will be our 12th, as we continue to build on the reporting undertaken by EWOS in 2010. The first and primary reason is to report on the sustainability of our activities and the progress we and our partners have achieved over the prior year. Second, it communicates our sustainability goals – our vision forward. Together, this reporting and forecasting increase our transparency and hold us publicly accountable for the commitments we make. From a day-to-day perspective, we have found our sustainability reports to be powerful risk mitigation tools for our customers and a source of pride for our internal colleagues.

Customers of course rely on them, as feed accounts for a major portion of aquaculture's environmental footprint, as do our customers' customers – retailers, restaurants, and food service companies. NGOs are also a key audience, as they continue to press for greater transparency from the industry. Finally, benchmarking schemes such as the World Benchmarking Alliance – which produces the bi-annual Seafood Stewardship Index – assess companies on their sustainability practices, including data provision.

Aquaculture solutions – for the farmer and feed segments

AAP: How do these help CQN and its clients achieve their sustainability goals?

Voorhees: It first makes sense to consider the question from a very pulled-back perspective; the "solution" that is driving all progress towards sustainability goals is greatly improved data availability. This improvement itself is driven by both technology – giving us the actual tools to collect information – and an emerging culture in the seafood community that realises that more data allow for better outcomes on farms, in feed ingredients and raw material supply chains, and through to how seafood is consumed in restaurants and at home.

More specifically, we create or participate in projects and programs that advance our and our customers' sustainability goals. For example, those developing and securing deforestation- and conversion-free raw materials help us advance many climate-related goals, and fishery improvement projects find solutions to unsustainable fishing practices and management. These solutions-focused efforts are integral to making meaningful and measurable progress.

Robb: Most specifically, one example of a technology solution is SalmoNIR, a device we developed for sampling and analysing the fat content, EPA, DHA and fillet colour of live salmon and has changed the game of quality monitoring. Farmers no longer have to sacrifice fish to perform these analyses, so they can sample hundreds of fish from cages without reducing biomass. This improves the overall productivity and efficiency of the farm, which means better feed conversion ratios (FCRs) and no "wasted" carbon emissions for fish that had spent time and energy growing but were not directed to human consumption. Tying to the point about data collection, this tech solution gives farmers more information about their fish, allowing them to make more informed decisions.

Another example of collaboration is through SeaBOS, where Cargill is leading the taskforce working on anti-microbial resistance in aquaculture. A key topic for one health – the health of people, animals and the environment being inextricably linked – and the best practice application of fish health management is focusing on most appropriate use of antibiotics. Through SeaBOS, Cargill is leading the development of a roadmap towards improved management of fish health, to reduce use of antibiotics and avoid those critical to human health as defined by WHO (World Health Organisation). We can only address topics like this through collaboration – vertically through the value chain and horizontally across competitors, together with governments to provide the appropriate regulatory framework and incentives.

Costs of sustainability

AAP: How does Cargill manage higher costs for sustainable raw materials?

Robb: We manage costs by working with both our suppliers and our customers to identify the ideal intersection of price and the sustainability attributes that we and our customers need. With climate and geopolitical challenges, the cost of all raw and finished materials is a topic of significant discussion across the food system. For us, continuing to provide feed that meets and makes progress towards our sustainability goals at a price that can be tolerated by consumers, we and our partners across the value chain have no other option but to work together in a collaborative way.

Voorhees: Finally, we'd like to reframe sustainability not as a cost, but as an investment. We are all aware of the global and local challenges we face, and the urgent need to address them, so ensuring the materials we use and the way we use them allows for their availability in the future is the only way forward.

AAP: In sourcing for high quality, sustainably sourced ingredients, how has the situation changed with rising raw material costs?

Voorhees: First, we must keep to our principles. The global community has no other choice but to continue headstrong into the sustainability challenges we face, and as one of the world's largest feed and food companies, Cargill's responsibility and opportunity to do that is very important. We of course also cannot compromise safety and quality. But, as you noted, doing that in a time of rising costs can be challenging. In response, we work with our value chains to understand the changes they are experiencing so we can better co-manage them. If we understand our suppliers on a daily or weekly basis, we can make small refinements to our operations and attempt to prevent a supply or cost catastrophe down the road.

Also, as we somewhat touched on before, sustainability of raw materials will reduce their, and our, vulnerability to

future volatility. Sustainability is resilience, and resilience should mean more manageable costs in the long-term. In the short term, we all have to find ways to manage when things get a little more expensive, and we're working hard to make good on our supply and sustainability commitments and do so at the lowest cost possible.

Traditionally, we have buffered rising costs by having a broad raw material basket for our feed ingredients. This means we are not dependent on any one supplier or raw material – as prices rise, we can switch. Recent events have seen raw material and energy prices rise globally, so this opportunity has changed. But this approach, together with developing sustainable production practices with our suppliers will help buffer against other events such as extreme weather impacts, more of which are predicted.

Pull effect to change mindset

AAP: European farmers and feed producers have taken sustainability as part of the business activity. Do you think that Asia Pacific's farmers and feed producers pay less attention to environmental sustainability?

Robb: If thinking about sustainability through the lens of its definition by existing sustainability standards, it is probably true that, on average, European industry and consumers both have more fully integrated sustainability into their practices and their demand for seafood. What is also true, though, is the diversity of production in Asia Pacific as compared to Europe, in terms of species, environments, farming methods, and undoubtedly in sustainability. There are many industry players across the region who are global leaders in sustainability – some are recognised as such, and many others are not. But farmers and feed producers anywhere can only pay attention to environmental sustainability if they are incentivised to do so, which brings in the social and economic pillars of holistic sustainability. Since Asia provides most of the seafood the world eats, the global community has a responsibility to support and improve those aspects as much as we do the environmental performance.

That said, however, there has been explosive development and widespread adoption of technologies focused on better farm management and greater sustainability in Europe that have not happened to the same degree in Asia Pacific. On-farm, you have water quality sensors and underwater cameras that allow farmers to constantly monitor their fish and the environment. Many farm have labs on site, or there are well-developed networks of labs, so disease testing and other health management technologies are more readily available than they often are in Asia. Furthermore, the amount of information these resources provide allows for intensive research and management of the challenges the European industry faces – not that these challenges have all been solved, and there are always new ones emerging, but in a world as complex as ours, information enables greater sustainability.

Voorhees: At Cargill, we can work through our networks to transfer both the tech and the understanding of sustainability demands from places like Europe, ideally making the industry more sustainable, productive and profitable. But exporting the "good stuff" isn't enough. We must also use our tools and capabilities to meet domestic seafood demand that is both more sustainable and fits local cultural and market expectations. Our ambition is to locally and globally couple sustainability with productivity and profitability.

New startup with big ambitions for aquaculture innovation and investment in Asia and Africa

By Michael Phillips and Aliesha Pigott

This is FUTUREFISH, a new startup on the aquaculture scene, founded by Dr Michael Phillips and Dr Rohana Subasinghe in early 2022. Both Phillips and Subasinghe have worked in aquaculture for many years. They are well established field specialists in research, and development, and have senior leadership roles and experience covering a diversity of aquaculture types and geographies.

The new company builds on these experiences, focussing on identifying, stimulating and accelerating investment into sustainable aquaculture innovation, start-ups and businesses in Africa, Asia and the Pacific. The company intends to help bridge the gap between promising aquaculture innovations and investment and seek new opportunities for investment in sustainable aquaculture in places and systems where aquaculture has the most significant potential for positive impact. Phillips noted, "Much progress has been made with sustainable aquaculture in recent years, but much more needs to be done in Africa, Asia and the Pacific to create change through aquaculture at the scale needed - on human and environmental health, our oceans and inland waters, and the world's response to climate change".

Increasingly recognised as an essential source of healthy and nutritious food—aquaculture can play a crucial role as a climate-resilient food source and livelihood option within a healthy and sustainable food system. Growing demand for fish and other "blue" foods makes aquaculture an active and exciting field of innovation and investment. Yet, the reality is that many innovations are not reaching farmers, are focussed on high-value species, are insufficient to achieve change at scale, or are blind to gender or the inclusion of small-scale actors. Low-income food-deficit countries and remote communities, where some of the greatest benefits of sustainable aquaculture might be achieved, are often not included in new investments. Risks from climate are poorly understood and not adequately factored into new investments or business strategies. Futurefish was conceived to work with like-minded change-oriented partners – trailblazing innovators, entrepreneurs, businesses and investors – to identify and create opportunities in such "difficult" places and challenges.

"Aquaculture is particularly important for food-deficit countries, where aquatic animals and plants are highly nutritious and offer unique health benefits. We believe that a greater focus on innovation and investment in low- and middle-income countries of Africa and Asia will create truly sustainable aquaculture for all and better outcomes for people, climate and the planet," said Subasinghe.

Boy selling fish traps in Sierra Leone. FUTUREFISH will work with partners to invest in opportunities that enable youth in Africa to improve their livelihoods through sustainable aquaculture.

Tilapia cage farm on Lake Toba, Indonesia. FUTUREFISH sees opportunities in the millions of SMEs across Asia and Africa where simple improvements in aquaculture technology can make a huge difference to productivity, profitability and overall sustainability.

The startup Futurefish will work across the aquaculture system in Africa and Asia but is paying particular attention to opportunities that are not well-served with innovation or investment:

Food and nutrition staples: Fish is a vital source of micronutrients, a commodity that should be both affordable and sustainable. Essential nutrients – such as calcium, zinc, and vitamins A and B12 – are critical for the development of children and the health of adults. Tilapia, carps and catfishes – often grown in mixed farming systems with small indigenous species – are food and nutrition "staples" for millions of people. These species can be farmed in sustainable ways, providing fast-growing and easy to grow on small- and large-scale farms, securing the nutritional requirements for many. Enabling farmers to deliver greater efficiency through a range of technology and management improvements – including genetics, health and management innovations – can be critical for millions of producers in Africa and Asia.

Smallholder farmers: Smallholders remain a significant contributor to rural economies – particularly in low- and middle-income countries in Africa and Asia and a mainstay of aquaculture production in several countries. New business models, inclusive digital approaches, respect for indigenous knowledge, inclusive innovations, policy, and investments are needed to provide new pathways with the right resources, partners and innovations.

African aquaculture: Africa needs a massive boost in fish production to meet projected demand in the next ten years.

Climate and environment: The ocean, the coastlines and coastal communities are disproportionately impacted by climate change. The degradation of coastal and marine ecosystems threatens the physical, economic, and food security of local communities and resources for global businesses. Aquaculture plays a vital role as a climate-resilient food source and livelihood option, yet understanding and managing risks and integrating aquaculture into? into a "carbon neutral" food system and company plans are at an early stage, and they need to be accelerated.

Women and gender: Women are present in all phases of the production, processing and distribution of fish and other "blue foods", contributing to the generation of wealth, the preservation of aquatic ecosystems and the maintenance of households and communities in rural and coastal regions. Yet, they are often underpaid, overworked, overlooked, and "hidden" from policy and investment at all levels. Futurefish is dedicated to empowering women in aquaculture; we want to see inclusivity at the forefront of change in aquaculture.

Finance and investment: Aquaculture is the fastest-growing food production system on earth. Already a USD250 billion industry, there is great potential to meet the future demand for more sustainable forms of protein in a sustainable way. There is increasing investment in aquaculture, but it is vital to ensure that such investments build ecosystem resilience, create better livelihoods, and meet consumer demand for humane and healthy food choices. Investment is not fully being targeted where it is needed, and there is a need to ensure finance is directed to where it can create the most significant impact on people and the planet.

Inclusive digital technology and data: Rapid advances are being made in digital technologies, artificial intelligence and cloud-based approaches for aquaculture – creating new insights, and enabling better management and market access to aquaculture stakeholders. Yet, many technologies highly focus on high-value commodities, and many farmers in rural areas across Africa and Asia lack access to the benefits that such technology might bring. Futurefish plans to create partnerships between digital start-ups and established businesses to encourage the growth of inclusive digital approaches and ways in which many can benefit from the advances being made.

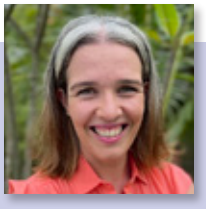
2022 is a fortuitous year to launch Futurefish. It is the year of the United Nations Ocean Conference and the International Year of Artisanal Fisheries and Aquaculture (IYAFA). Subasinghe is the International Steering Committee Vice-Chairperson. 2022 is also the year when action is required on the significant global policy commitments from 2021 - a year in which the UN Food Systems Conference brought new attention to the role of aquaculture and fisheries in sustainable and healthy food systems when the COP-26 highlighted the importance of action on climate and food security. In contrast, the UN Convention on Biodiversity highlighted the challenge of reversing the decline in nature - all key areas where aquaculture - "done right" - can play an important role. It is also a year when - amongst multiple challenges -

Backyard production of algae in Vietnam. Algae – in its many diverse forms – are a key innovation area with vast potential for food and other products.

the need to accelerate progress towards the Sustainable Development Goals by 2030 and climate mitigation is becoming more apparent.

Futurefish is in "startup" mode in 2022, building a diverse team and partnerships with like-minded change-oriented people and partners to work across the spectrum from innovation to investment. Early work in 2022 will involve an intense consultation process with innovators, industry partners and start-ups to assess market gaps and investment opportunities in Africa and Asia whilst building a network of partners and community to accelerate progress from innovation to investment to impact.

There is a bright future ahead for aquaculture, but aquaculture must do better to get there. – Futurefish is looking to work with trailblazing entrepreneurs and businesses with big ideas to help make that change a reality.



Michael Phillips, PhD is Co-Founder and Director, Futurefish, based in the UK.

Aliesha Huia Piggott is Communications Manager, Futurefish, based in Malaysia.
Email: aliesha@futurefish.org

More information: www.futurefish.org

Shrimp grow stronger and healthier with krill meal in the feed

By Atul Barman

Seafood is one of the best sources of omega-3 fatty acids, as well as amino acids, vitamins, and minerals. Not only are these nutrients important to humans, but they are also essential for farmed aquaculture species such as shrimp. Shrimp farmers aim to raise healthy and high-quality products for human consumption, and to do so, they need a dietary feed composed of the most effective, nutrient-rich ingredients on the market.

Antarctic krill is the source of one such ingredient for shrimp feeds. Krill are tiny crustaceans found in the Southern Ocean in Antarctica. These small, shrimp-like creatures are located at the bottom trophic level of the food chain, consuming free floating algae which contribute to their nutrient rich nature.

A sustainable source of nutrition for shrimp

The krill fishery is carefully monitored for its sustainability. Krill can only be fished in one area off the Antarctic Peninsula, and krill harvesters are restricted to catching just one percent of the estimated biomass in that area. The goal is to ensure that the krill biomass keeps growing and that krill can continue to be a part of the food chain for other marine wildlife. The wellbeing of Antarctic krill is assessed regularly by the Commission for Conservation of Antarctic Marine Living Resources (CCAMLR), and they have reported that the krill fishery is amongst the best managed in the world.

With a healthy supply and its status as a sustainable marine resource, krill has emerged as an ideal replacement for fishmeal in shrimp feeds. Supply of fishmeal is not enough for rising aquaculture production and alternative protein sources are needed. Krill has been proven through scientific studies to have better nutritional benefits than other alternatives, such as plant-based or animal meals.

A super ingredient for shrimp feed

Krill meal contains up to 58% protein with a well-balanced amino acid profile. It contains essential omega-3 fatty acids, including docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), which have proven to be essential for growth, survival and disease mitigation in shrimp. Krill meal also includes trimethylamine N-oxide (TMAO), a molecule generated from choline, betaine and carnitine, as well as nucleotides, all of which help make the feed more attractive for shrimp.

A tastier feed to help shrimp grow

Shrimp producers indicate that krill makes the feed more attractive and taste better to the shrimp. This is a unique attribute of krill meal; all shrimp feeds, especially in starter feeds, need to have enough nutrients for shrimp to both grow and survive. The shrimp nursery is a very important stage, as the shrimp are kept at high densities in tightly controlled environments. Higher feed intake improves chances of an overall high performing crop.

Shrimp feed manufacturers are also increasingly aware of the benefits of krill meal as a supplement or replacement ingredient for fishmeal in their feeds. Krill gives manufacturers more flexibility with their ingredients, as even low amounts of krill meal combined with other alternatives, have been shown to positively affect the feed's attractability to shrimp. This means that they can maintain cost levels, diversify their ingredients and improve their performance, all at the same time – thanks to kr ill.

Improve survival rates in nurseries and culture ponds

The nursery and earthen pond stages can be stressful for shrimp, as it is a critical time in their development. There are often low survival rates reported by farmers, which can result in financial losses for them.

Scientific studies have tested out krill meal as a supplement to the feed at these delicate, early developmental stages. The results show that with krill in the feed mix, survival rates can improve. Krill helps to reduce the initial stress related to transport and the dense environment due to the antioxidants it delivers to the shrimp.

Disease is another factor that impacts the survival rates of shrimp. In particular, white faeces syndrome (WFS) can cause severe damage to the shrimp crop, leading to lower returns for the farmer. Krill meal as a feed ingredient stimulates the hepatopancreas which helps with health and immunity.

One ingredient with a multitude of benefits

Shrimp farmers are seeing krill meal as a much-needed life raft in an already challenged industry. The shrimp industry depends on high-quality, nutrient-rich feed ingredients for farmers to continue to stay profitable.

Krill's attractiveness as a feed ingredient is second-to-none, which is why it is serving as the industry's leading 'sustainable ingredient' that contributes to increased growth, robustness and overall health of farmed shrimp.

Atul Barman is Director & General Manager Aker Biomarine India.
Email: atul.barmann@akerbiomarine.com

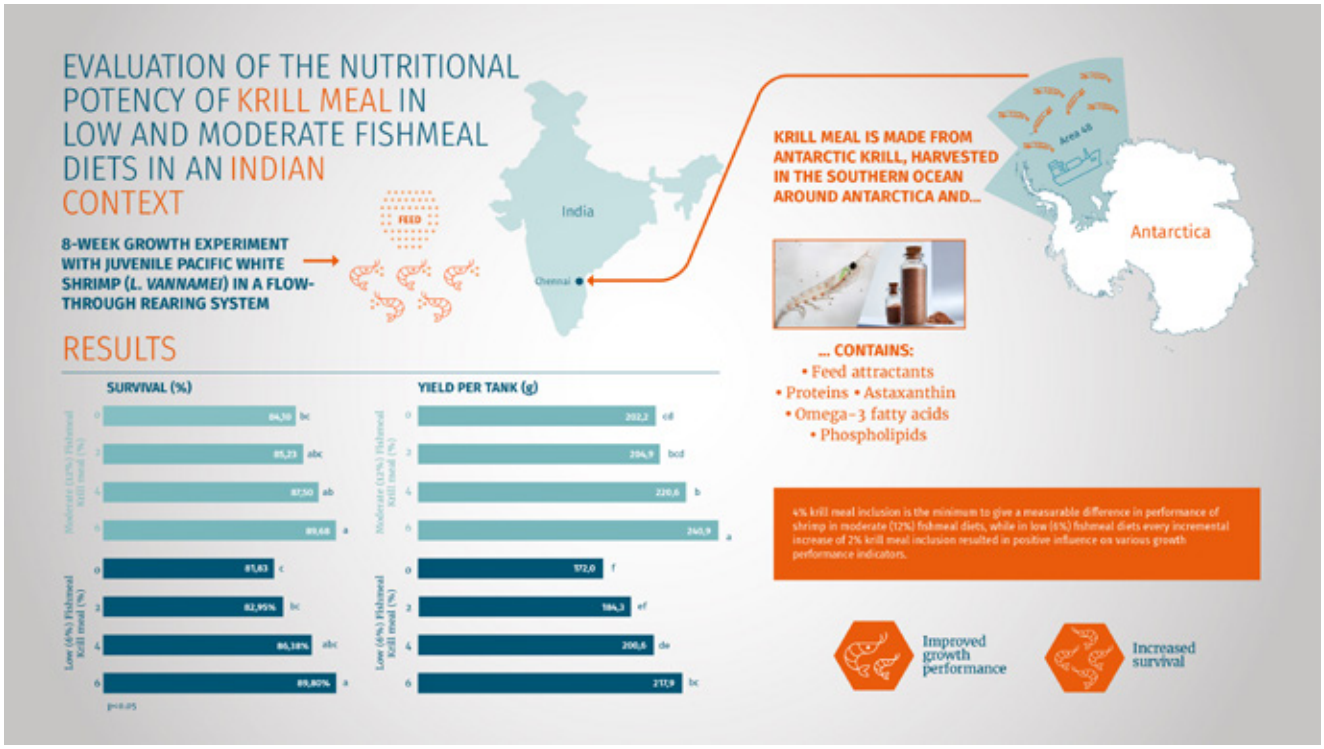
SHRIMP PREFER FEED WITH KRILL

Krill provides a beneficial package of nutrients containing omega-3 phospholipids, proteins and attractants. This makes shrimp feed with krill both a shrimp favorite as well as nutritious.

QRILL™ AQUA
BY AKER BIOMARINE

New study reveals krill meal's high potential for developing sustainable shrimp feed formulations

Dr K. Ambasankar from India's Central Institute of Brackishwater Aquaculture (ICAR) discusses how krill meal is a beneficial functional ingredient for whiteleg shrimp (*Penaeus vannamei*). In an eight-week feeding trial, results reveal that inclusion of 4 to 6% krill meal in the diet can lead to higher body weight and greater survival among the shrimp.



What is the situation in shrimp farming today in India (and globally) that led to this study?

India is one of the world's largest marine shrimp exporters, earning it the title of "shrimp garden of the world". In 2020-21, the country exported nearly 1.15 million tonnes of seafood, with the majority comprising farmed frozen shrimp. An estimate on farmed shrimp production in 2021 was around 680,000 tonnes. A key market opportunity is large sized shrimp and shrimp farmers in India continue to seek ways to improve profitability and productivity, with higher survival rates.

India is a major exporter of shrimp to the US, European and Asian markets. However, its position in the global shrimp industry will depend on its ability to remain competitive, be sustainable and meet higher productivity targets – facilitated through healthier and larger shrimp. Feed plays a major role in helping shrimp producers achieve these goals, which is why it is essential to uncover functional ingredients, such as krill meal, that can help farmers achieve optimal results.

What was the aim of this study?

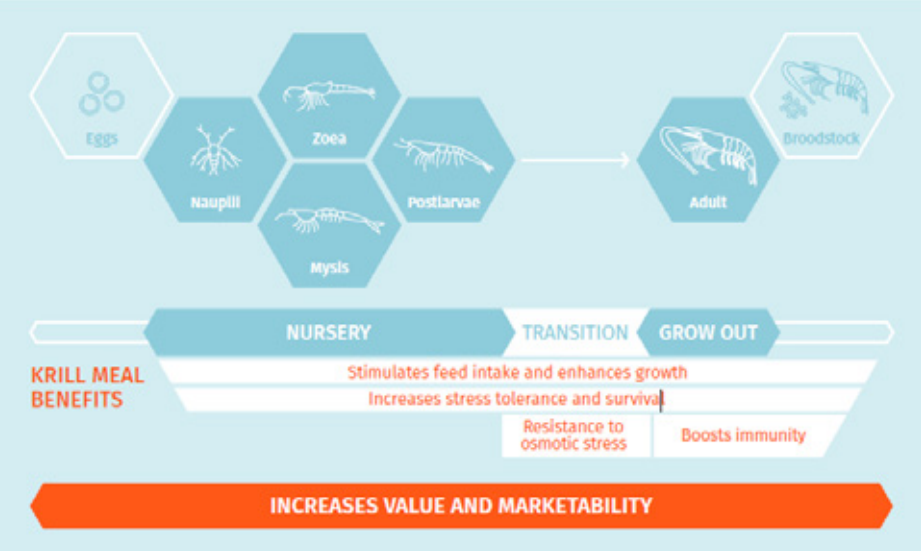
Fishmeal and fish oil are still considered the most nutritionally balanced and most digestible ingredients in shrimp feed. However, with restricted supplies and increasing prices, feed formulators continue to experiment with several nutritional alternatives to be able to reduce the use of fishmeal.

The aim of this trial was to find out if krill meal is a beneficial and functional ingredient for increasing body weight and survival for the whiteleg shrimp *Penaeus vannamei*. In addition to shrimp growth performance, the present study focuses on carcass nutrient composition (proximate and fatty acids levels), immune gene expression, histology of hepatopancreas and haemocyte count. This is in relation to three different krill meal inclusion levels (2, 4 and 6%) at two different fishmeal inclusion levels (6 and 12%). This baseline data obtained in an Indian context will help to identify the best areas for utilisation and limitations of krill meal in commercial shrimp feed formulations.

How was the experiment set up?

Feeding trials were conducted at the indoor wet laboratory at the ICAR facility in Chennai, India. There were eight iso nitrogenous and isolipidic diets formulated to contain 36% crude protein and 5.5% crude lipid. Krill meal was included at 0, 2, 4 and 6% in the moderate fishmeal (12%) diets and likewise in the low (6%) fishmeal diets.

We cultured post larvae to 0.55g juvenile shrimp over eight weeks and fed them at 8% of total biomass. The ration was divided into three meals daily throughout the experiment duration. We also confirmed that the juveniles were free from all the OIE-listed pathogens to rule out any disease risks. We used a total of 32 fiberglass tanks of 350L. There were four replications per treatment.



Final measurements were on weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), apparent protein utilisation (APU) and survival. After the experiment we sampled shrimp in the inter-molt stage for the quantification of immune gene expression. We performed histology of the hepatopancreas and analysed body composition including proximate and fatty acids levels.

What are the key findings from the study?

These were:

- Shrimp fed 6% krill meal in the moderate (12%) fishmeal diet had the highest body weight at the end of the study.
- Survival rates significantly increased in the groups fed 4% and 6% krill meal in the diet.
- When 6% krill meal was included in the diet, shrimp showed a higher content of n-3 polyunsaturated fatty acids.
- Shrimp fed 2% krill meal in a diet containing 12% fishmeal significantly increased the expression of six immune-related genes in the hepatopancreas.
- In particular, a diet with low (6%) fishmeal showed markedly improved performance even with a small amount of krill meal (2%) compared to the respective control.
- The inclusion of krill meal has enhanced the level of n-3 PUFAs, particularly EPA and DHA in the shrimp body, irrespective of the dietary fishmeal level, which is the most beneficial feature for human nutrition.
- In addition, krill meal was found to be a good source of methionine (3.96 g/16gN) in comparison to 2.84g/16gN in Indian fishmeal.

What are key takeaways from the study?

The results of this experiment showed that krill meal, when supplemented in amounts between 4% and 6%, was a beneficial functional ingredient for both moderate (12%) and low (6%) fishmeal diets. This finding is based on the increased growth performance in the groups fed krill meal and overall improved survival rates, leading us to conclude that krill meal can be a viable supplement to fishmeal in shrimp feeds.

The functional aspect of the krill meal was demonstrated by the correlation of important immune genes and combined dietary inclusion of fishmeal and krill meal protein. Krill meal can be a potential functional ingredient in *P. vannamei* feed. It contributes to a sustainable, cost-effective and health-promoting feed with a maximum fishmeal reduction without compromising on growth performance.

Where can readers find more information?

The article published in Aquaculture by K. Ambasankar, J. Syama Dayal, K.P. Kumaraguru Vasagam, T. Sivaramakrishnan, K. P. Sandeep, A. Panigrahi, R. Ananda Raja, Lena Burri, K.K. Vijayan "Growth, fatty acid composition, immune-related gene expression, histology and haematology indices of *Penaeus vannamei* fed graded levels of Antarctic krill meal at two different fishmeal concentrations" can be found here https://doi.org/10.1016/j.aquaculture.2022.738069

Lysophospholipid-based digestive enhancer to boost growth performance and digestion mechanisms of shrimp under different dietary cholesterol levels

By Yu-Hung Lin and Waldo G. Nuez-Ortín

For many years the aquaculture industry has sought to improve sustainability through reduction in the use of fishmeal in aquafeeds. Soybean meal is a widely used alternative to fish meal in shrimp feed because of its well-balanced nutritional composition and easy availability. However, the use of soybean meal in shrimp feed should be carefully considered due to its deficiency of some nutrients, especially cholesterol. Cholesterol is a critical dietary requirement for shrimp which lacks the ability to *de novo* synthesise this nutrient (NRC, 2011). Cholesterol requirements for white shrimp are reported to be 0.11-0.14% (NRC, 2011), while cholesterol levels in standard shrimp feed formulations currently range between 0.05% and 0.1%. Therefore, increasing soybean meal inclusion levels decrease cholesterol concentrations in the shrimp hepatopancreas and haemolymph (Lin et al., 2017). Such hypocholesterolemia is attributed to both deficiency of cholesterol in soybean meal and poor cholesterol utilisation by the shrimp.

Shrimp lack a bile juice system, as a result of which the lipid digestion process is not as efficient as in fish. Digestibility enhancers based on natural emulsifying agents have been proven to be capable of complementing the process of emulsification and optimising the digestion and utilisation of important lipidic nutrients such as cholesterol.

Aqualyso® (Adisseo) is a lysophospholipid-based additive produced by the controlled hydrolysis of phospholipids in soybean lecithin with phospholipase A2. Lecithin facilitates the digestion and absorption of lipids. Given the superior emulsifying properties of Aqualyso in relation to lecithin, a common application nowadays in shrimp feeds is lecithin replacement to reduce formulation cost and maintain growth performance. A growth trial was conducted to investigate the benefits of lysophospholipid-based Aqualyso in current shrimp feed formulations containing high and low concentrations of cholesterol. Dietary levels of fish meal and soybean meal were adjusted to provide high (0.12%) and low (0.05%) cholesterol concentrations in the experimental feeds.

Experimental setup

Four isoproteic and isolipidic experimental feeds were formulated and are presented in Table 1. Two control feeds containing 1% lecithin were designed, with either high or low concentrations of cholesterol: high cholesterol diet (HIGH CHOL, 0.12%) and low cholesterol diet (LOW CHOL, 0.05%). Aqualyso (AQL) was supplemented at 0.1% into both formulations: HIGH CHOL+0.1% AQL and LOW CHOL+0.1% AQL. Sinking shrimp pellets were produced using a mincer with a 2mm diameter die, dried in an oven at 60°C, and stored at -20°C until use.

The four experimental feeds were randomly assigned to 12 tanks (300L, 3 replicates per treatment) in a close recirculation system. Twenty shrimp (2.39±0.02g) were stocked in each tank. The system consisted of biological filters, protein skimmer and UV light to maintain water quality. The water temperature of the rearing system was controlled at 28 ± 1°C. The shrimp were fed to 6% of their wet weight 4 times per day at 07:00, 12:00, 17:00 and 22:00h. Shrimp were weighed once every 2 weeks and half of the rearing water was exchanged at the same time. Shrimp were fed the experimental diets over 8 weeks.

	HIGH CHOL	HIGH CHOL + 0.1% AQL	LOW CHOL	LOW CHOL + 0.1% AQL
Ingredients (%)				
Fish meal	20	20	7	7
Soybean meal	25	25	43.5	43.5
Fish oil	3	3	1	1
Soybean oil (refined)	0	0	3	3
Soy lecithin	1	1	1	1
Aqualyso®	0	0.1	0	0.1
Alpha-cellulose	6.5	6.0	3.0	2.5
Others*	29.9	29.9	29.9	29.9
Composition (%)				
Moisture	9.32	11.04	9.96	11.01
Ash	7.62	6.40	7.57	6.72
Crude protein	37.15	36.68	37.15	36.85
Crude fat	7.64	7.90	7.74	8.12
Cholesterol	0.118	0.052	0.122	0.053

*includes 15% fermented soybean meal, 8% corn starch, 10% alpha-starch, 7% squid liver meal, 1.5% choline chloride, 1% vitamin premix and 2% mineral premix.

Table 1. Formulation and composition of the experimental diets.

At the end of the feeding trial, the shrimp were bulk weighed to calculate growth performance. Following this, hepatopancreas were randomly collected from two shrimp in each tank. Gene expression of digestive enzymes, including chymotrypsin, trypsin, amylase and lipase, were measured. Primer design and relative quantification followed the description by Castro-Ruiz et al. (2021) and Livak and Schmittgen (2001).

Data was assessed for normality and variance homogeneity using the Kolmogorov-Smirnov test and Bartlett's test, respectively. The results were analysed by a one-way analysis of variance (ANOVA). When the ANOVA identified differences among the groups, multiple comparisons were made among the means using the Duncan's multiple range test. Statistical significance was determined by setting the aggregate type I error to $p<0.05$.

Supplementation supports growth performance

Supplementation of the lysophospholipid-based digestive enhancer supported feed intake and growth performance of shrimp fed high and low cholesterol feeds (Figure 1). Feed intake significantly improved by 13 and 21% with

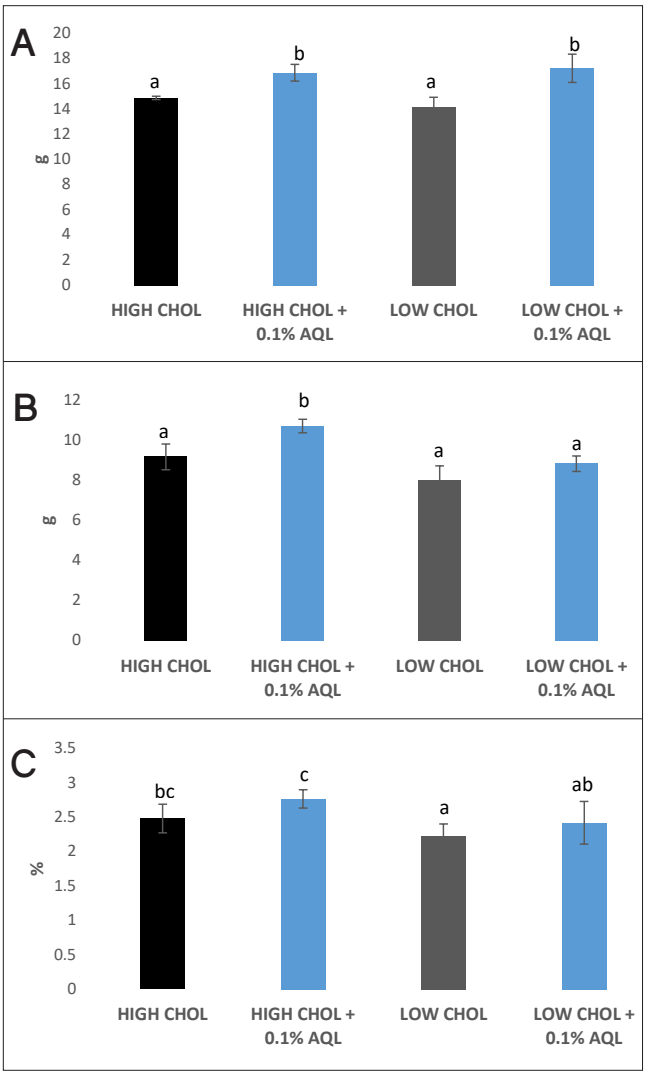


Figure 1. Effects of dietary lysophospholipids (Aqualyso®, AQL) on feed intake (A), weight gain (B) and specific growth rate (C) of white shrimp fed diets with high cholesterol (HIGH CHOL) or low cholesterol (LOW CHOL). Bars with different letters indicate significant differences ($p<0.05$).

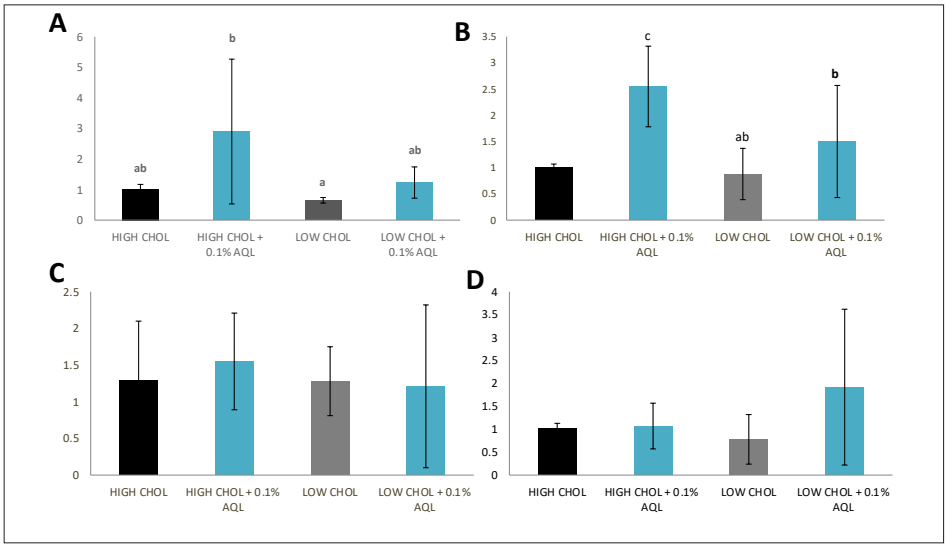


Figure 2. Effects of dietary lysophospholipids (Aqualyso®, AQL) on relative gene expression of chymotrypsin (A), trypsin (B), amylase (C) and lipase (D) of white shrimp fed diets with high cholesterol (HIGH CHOL) or low cholesterol (LOW CHOL). Bars with different letters indicate that they are significantly different ($p<0.05$) from one another.

supplementation in the high and low cholesterol feeds, respectively. The best growth effects were found in the high cholesterol feed supplemented with Aqualyso, showing significant improvements of 16% and 11% in weight gain and specific growth rate (SGR), respectively. A similar pattern was observed in the low cholesterol feed; with supplementation the numerical improvements were 10% and 8% in weight gain and SGR, respectively. More interestingly, supplementation in the low cholesterol feed matched the performance of the high cholesterol feed, proving the efficacy of this lysophospholipid-based digestive enhancer to reduce formulation cost while maintaining the performance of a better quality feed. Additive supplementation did not significantly affect feed conversion efficiencies of the diets containing high and low cholesterol levels. Neither cholesterol levels nor additive supplementation affected survival, which averaged 76% across all treatments.

We have previously demonstrated that 0.1% lysophospholipid-based digestive enhancer can successfully replace 0.75-1% lecithin of a control feed containing 2% lecithin (Lin et al. 2021). In the present study, an average amount of 1% soy lecithin was added to all diets to satisfy the minimal phospholipid requirement for shrimp (NRC, 2011). Under such formulation strategy, the similar growth performance between the high cholesterol feed and the Aqualyso-supplemented low cholesterol feed can be attributed to the additive effect to improve digestive emulsification and promote a more efficient absorption and utilisation of cholesterol in 1% lecithin feeds.

Previous studies in fish, such as with turbot and channel catfish, have also reported a positive effect of lysophospholipid supplementation that is believed to be linked to a better absorption and utilisation of essential lipidic nutrients (Li et al., 2019; Liu et al., 2019). In salmon, more recent unpublished data show that Aqualyso accelerates the absorption and transport of nutrients in the intestine as well as the processing of nutrients in the liver.

Influencing digestive enzymatic activity

The present study also showed that Aqualyso can potentially influence digestive enzymatic activity. Gene expression analysis of proteases, such as chymotrypsin and trypsin, were upregulated in both high and low cholesterol feeds (Figure 2). However, only the supplementation in the high cholesterol feed proved to be significant. A similar but not significant upregulation pattern was observed for amylase and lipase (Figure 2). Specifically, the lysophospholipid supplementation numerically induced a 1.5-fold change in the gene expression of lipase in the low cholesterol feed, suggesting an optimisation of lipase activity due to enhanced emulsification. The regulatory pattern in the expression of proteases, amylase and lipase were in line with the increased intake and better performance observed in the Aqualyso supplemented groups, indicating that improved performance can be attributed to increased feed intake supported by the digestive mechanisms keeping up with the increasing digestive demands.

In summary, we demonstrated in this present study that 0.1% lysophospholipid-based Aqualyso® improves growth performance and digestive enzyme gene expression in shrimp fed different cholesterol levels. Given the need for further reducing fishmeal inclusion in shrimp feeds, along with the increasing cost of lecithin, Aqualyso supplementation under lecithin replacement strategies seems an effective strategy to promote sustainability and optimise the feed cost and performance of shrimp feeds.

The Aqua Nutrition Platform by Adisseo continues to combine species-specific research on Aqualyso application strategies and formulation experience while providing services related to feed formulation and processing.

Professor Yu-Hung Lin is with the Department of Aquaculture, National Pingtung University of Science and Technology, Taiwan.
Email: yuhunglin@mail.npust.edu.tw

Waldo G. Nuez-Ortín, PhD is Lead Scientist Aquaculture, Adisseo, Belgium.
Email: waldo.nuezortin@adisseo.com

New heights with industrial symbiosis and scalability in insect production

Innovafeed stands tall with sustainability and assurance of feedstock and renewable energy supplies

By Zuridah Merican

Innovafeed's vertical farming model - For every hectare of insect vertical farm, 100 hectares of arable land is required to produce equivalent amount of protein from soy.

The global insect production sector is characterised by the growing number of startups and innovators in every corner of the world. Europe, however, is where several leaders in insect technology first started. When the European Union approved the use of insect meals in aquafeeds in July 2017, the aquafeed industry became the main target market for insect technology companies, according to the International Platform of Insects for Food and Feed (IPIFF), an EU non-profit organisation for the insect production sector. By 2030, IPIFF expects 40% of volumes will be for this market with 10% of the fish consumed in the EU derived from fish farms that use insect protein in their aquafeed formulations. This would depend on how fast insect producers upscale. Scalability is an industry challenge for insect technology innovators.

Here in Asia, with the push for a sustainable high protein alternative to fishmeal, while there is already an acceptance of insect meals, a concern often expressed is stable and larger volumes.

Industrial symbiosis

Nestled in Nesle in northern France, insect producer, Innovafeed is convinced that its unique "industrial symbiosis" production model puts it ahead of its competitors. There is a symbiotic relationship among the three companies within the same industrial site. Tereos, a starch plant, supplies 100% of the wet agriculture feedstock - wheat bran and stillage - to Innovafeed which uses them as is. The advantage for Tereos is that it does not need to dry its by-product. Kogeban produces energy using wood biomass to run a turbine to produce electricity for the national grid and steam for Tereos. Innovafeed has a hydro condenser around the turbine and the heat generated is channelled as hot water to heat the insect factory.

"Therefore, we have 100% green energy from Kogeban, as we also take waste steam from Kogeban for our use. Therefore, 60% of the energy used at our plant is waste energy which has been a huge advantage for us amidst this Ukraine war and high energy costs. At all our sites, this is the model, co-location with energy and feedstock suppliers. This zero-waste circular model saves 57,000 tonnes of CO_2 emissions per year. We can valorise those energy savings through various mechanisms such as white certificates or carbon credits," explained Maye Walraven, VP of Business Development at Innovafeed.

She added how insect ingredients, in replacing fishmeal or palm oil in aquafeeds, save 45,000 tonnes of marine resources and 1,800ha of arable land, respectively.

"This symbiosis model is really what makes us more sustainable. If we did not have this model, our carbon footprint would be 80% higher due to the drying of the co-products. Our cost would also be higher because of the energy requirement," explained Walraven. "As this facility and others that we plan to set up are in rural areas, we provide jobs for the local community. In fact, here in Nesle, we employ 110 people from the local community."

Scalability

The technology development for Innovafeed began in 2016 with R&D in Genopole d'Evry. Here, its R&D and engineering teams developed its cutting-edge technology- a unique technology to reproduce on a large scale the life cycle of the insect, optimise each insect production cycle and derive the most efficient way for meal and oil production.

Then came the production of several hundreds of tonnes/year at the Gouzeaucourt pilot facility. Now it has this commercial site in Nesle, with its disruptive technology. This is an entirely automated vertical farm model covering 25,000m² which combines several floors to reach more than 12m in height. A modular design permits more expansion and the plan is to increase volumes vertically and bring production up to 15,000 tonnes/year. Innovafeed says to date it is the world's largest insect producer.

In February, Innovafeed and Archer-Daniels-Midland (ADM) announced their collaboration to build the world's largest insect protein farm in Decatur, Illinois. The R&D centre is set to begin construction in 4Q 2022. This will have a similar symbiosis arrangement (energy and feed substrate supply) with a large ethanol producer for 60,000 tonnes of insect proteins. Part of these volumes will be destined for ADM's pet food business. This partnership with ADM follows recent US regulations allowing the use of black soldier fly (BSF) in food for dogs. Innovafeed has plans for more commercial facilities in other parts of the world. This commercial plant in Nesle was started in November 2020 after 2 years of construction. While the Covid-19 pandemic delayed progress and supplies, it did not disrupt their business model. In fact, according to Walraven, it reaffirms the resilience of its business model and the need for sustainable, local and quality products.

Best in class for economic performance

This comes from this symbiosis model/relationship with Tereos which provides a traceable, steady quality of feedstock as part of a long-term contract. Again, 60% of the energy comes from waste energy. In terms of costs, this best in class for economic performance is based on the cost of producing a unit of ingredient, i.e. 1,000kg of insect proteins, 300kg of oil and 3,500kg of fertiliser.

"This is the symbiosis model which we have made to be as competitive as possible and the scale that we are targeting to produce insect meal. We think we are the only insect producer with this symbiosis model and take this as our cost advantage and to produce our products in a sustainable way."

"This correlation to the symbiosis model is really what makes us more sustainable,"- Maye Walraven, VP of Business Development at Innovafeed.

Walraven added that when founders, Aude Guo, Bastien Oggeri and Clément Ray created Innovafeed in 2016, they were aware of the circular nature of insects as up cyclers but wanted to do more and contribute to the construction of tomorrow's sustainable food system.

Steps in *Hermetia illucens* meal production

The BSF - black soldier fly *Hermetia illucens* - was chosen because of its efficiency for large-scale production and its nutritional profile where the amino acid composition is close to that of fishmeal for aquafeeds. The best stage to harvest is the larvae stage, when biomass is high, the ratio of protein: oil is highest and the ratio of protein: chitin ratio is best.

"We have already developed the technology to get the best from the protein, oils and chitin. More can be done such as hydrolysis to fractionation and transformation to get more from waste and by-products. There is a world of things our innovation team can do aside from genetic selection in this insect industry. By year-end, we will turn our Gouzeaucourt facility into an innovation centre."

The engineering team has developed fully automated farms deploying artificial intelligence (AI) all along the production chain. BSF reproduce and develop into larvae in dedicated greenhouse buildings with a controlled environmental condition - temperature and humidity are maintained using steam obtained from Kogeban. Among the various pain points for the engineering team is maintaining airflow in such tall structures. "There are numerous limiting factors, but we are overcoming them and optimising our production. Thanks to genetic selection and control of environmental conditions, we have significantly reduced the time to harvest since the beginning of our operations."

View of the farm in Nesle with four sectors; from right, anticlockwise, Reproduction, Growth, Sieving and Processing. Two separate piping brings in energy and agriculture feedstock.

During the walk-through of this production process, it was obvious how the R&D and engineering teams have excelled with robotics and AI to micromanage production and automate for efficiency without any

The 300m pipeline that feeds the stillage which is 80% water and bran from Tereos to Innovafeed into storage tanks with mixers operable in real-time to get the right mix of feed substrate.

The R&D and engineering teams have excelled with robotics and artificial intelligence to micromanage production and automate for efficiency without any human intervention.

human intervention. Several technological developments are proprietary to Innovafeed.

In Europe, BSF is regarded as a non-invasive species but here, escapees are prevented by the layers of net cages in enclosures within the greenhouse. Under EU rules, the processing area is categorised as food production and therefore, requires a completely different sanitary environment than the culture area.

"Out of this process, Innovafeed produces insect meal with up to 70% protein for the aquafeed and insect oils with 45% lauric acid for poultry and swine feed markets. We also have product lines for pet food production. Frass is used as an organic fertiliser to close the nitrogen loop and boost crops' performances," said Walraven.

In terms of consistency, Innovafeed assures this with the quality control process in place. Consistency in the feedstock used is monitored by the quality control team and there is HACCP as well as complete traceability with detailed batch-by-batch monitoring at all steps of the process from the substrate to the level of the final products. As feed ingredient manufacturers, they need to adhere to the strict regulations in Europe, such as those relating to microbiological, pollutants and mycotoxins contaminations. It must also meet the requirements of large feed producers who also run audits of the factory.

Larvae are dropped into boiling water to stop the enzymatic process before low temperature drying.

Targeting aquafeeds

Innovafeed has focused on salmon and shrimp feeds as their target markets. Walraven said, "We see carnivorous species as those in need of high-quality protein. For salmon, we see our insect protein as a novel ingredient that feed formulators can rely on to produce sustainable, high quality and functional feeds. We have demonstrated that our insect protein can replace fishmeal up to 100% in formulations."

Innovafeed is part of the EU research consortium Millennial Salmon to innovate and create the most sustainably farmed salmon using novel ingredients from the circular economy and with a low carbon footprint. With Skretting, it has launched a trout feed, replacing 50% of the fishmeal with insect protein. In this feed, algal oil replaced fish oil and trout fed on this feed have been rebranded as sustainable trout. "We have a partnership with Auchan to produce insect protein fed trout, pigs and poultry. We are the only insect meal producer to do that. Trout sales increased 40% after the launch of the product."

In 2021, Innovafeed launched a new high-performance ingredient, NovaGain™, designed for shrimp feed. At inclusion rates of 5-10%, studies showed 20-30% improvement in performance, in terms of both feed conversion ratio (FCR) and specific growth rate (SGR) of shrimp. The bioactive peptides in the meal combine both nutritional and functional benefits, the latter, particularly with white spot syndrome virus (WSSV) and acute hepatopancreatic necrosis disease (APHND). The basis of this is that ingredients derived from BSF are rich in compounds that can support the innate immune response of shrimp and chitin is a natural compound which acts as an immunostimulant (Richardson and Walraven, 2021).

Henceforth from 2022, Innovafeed will invest to develop new production sites in France and internationally. In five years, it expects the US plant to be running alongside another 4-5 plants under construction by 2030. Currently, Innovafeed has announced large offtakes with Cargill for aquafeeds and monogastrics in Europe and ADM for pet food in the US.

Reference

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Mycotoxins in Asian aquafeeds

Contamination in raw materials and finished aquafeeds in Asia from the Alltech Aqua Mycotoxin Survey

By Sudhakar V. S. Govindam and Henry Wong

The aquafeed industry is fast evolving with the development of advanced technologies, including feed processing technology, the application of novel ingredients and nutritional breakthroughs. There is a lot of interest in focusing on alternative ingredients to reduce the reliance on fishmeal and fish oil from capture fisheries in formulations to meet sustainability requirements.

The most common and economically viable option is to partially substitute marine ingredients in aquafeed, which nutritionists currently adopt, with ingredients derived from plants and their byproducts. However, the inclusion of plant-based ingredients in aquafeed presents some challenges to fish and shrimp with regards to digestibility, antinutritional factors, palatability, nutritional profiles including minerals and amino acids, and mycotoxin contamination. While information on mycotoxin contamination for grains and their byproducts is widely available, allowing feed producers to manage the mycotoxin risks in feed, information with regards to aquafeed samples is scarce.

In addition, challenges posed by mycotoxins in aquatic animals are less studied and often neglected. Similar to other vertebrates, fish are more sensitive to mycotoxins when multiple forms are present in the feed. A mycotoxin may be present at a 'safe' level in isolation, but when combined with another mycotoxin (also at a 'safe' level on its own), both can act synergistically to produce a more significant toxic effect in fish. Mycotoxins impair optimum animal performance by affecting intestinal, organ and immune systems, which, in turn, adversely impact business profitability. Although some stakeholders have begun to adopt best practices in testing mycotoxin levels in raw materials, many overlook the possible mycotoxin risks and their impacts on aquatic animal performances.

Alltech Aqua Mycotoxin Survey 2021

To understand the landscape of the mycotoxin challenges in the Asia Pacific region, Alltech conducted a survey across the region to get an indication of the mycotoxin risks in aquaculture. During 2021, about 200 samples, including aquafeed and commonly used raw materials, were collected from six targeted countries (Bangladesh, India, China, Malaysia and Vietnam). The samples were analysed for multiple mycotoxins utilising Alltech 37+® mycotoxin analysis (an LC-MS-based system) or the Alltech RAPIREAD® system (ELISA-based system).

Six varieties of commonly used aquafeed raw materials (corn gluten meal (CGM), distiller's dried grains with solubles (DDGS), rice bran, soybean meal, wheat flour and canola meal) were analysed for six mycotoxins (aflatoxins, ochratoxin, deoxynivalenol, T-2/HT-2 toxins, fumonisins and zearalenone). These raw material samples were analysed for their mycotoxin levels and their risks in shrimp and marine and freshwater fish using RAPIREAD technology. The cumulative effect of multiple mycotoxins was expressed as a risk equivalent quantity (REQ) number. The REQ provides a single toxicity factor for the feedstuff based on the toxicity of each compound relative to aflatoxin B (the most toxic of the mycotoxins) and its concentration.

The overall REQ of all the raw materials combined was at high-risk levels across the species analysed, shrimp, and marine fish (seabass/seabream) and tilapia is shown in Table 1 and Figure 1. Note that deoxynivalenol (DON), T-2/HT-2 toxins and zearalenone were present at high-risk levels.

Average concentration of mycotoxins above LOQ		
Mycotoxins	Average (ppb)	Maximum (ppb)
Aflatoxins	8	75
Ochratoxin	19	119
Deoxynivalenol	1804	4,400
T2/HT2 toxins	<150	65
Fumonisins	899	6,149
Zearalenone	327	694
Ergot toxins	not analysed	

Table 1. Average concentration of mycotoxins in all raw materials. LOQ= Limits of quantification.

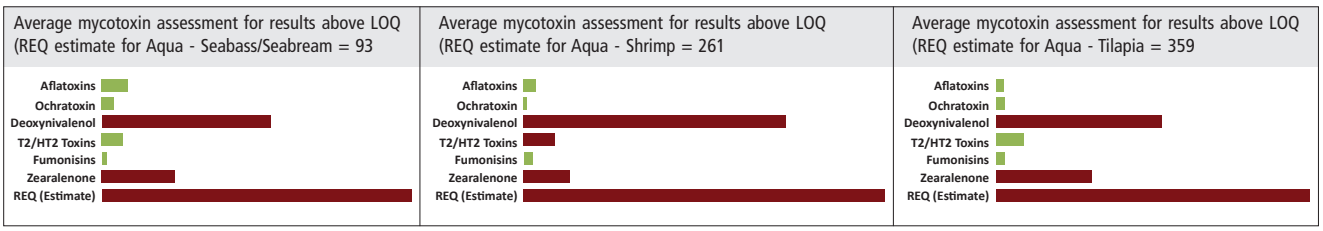


Figure 1. Average mycotoxin assessment and REQ estimates by species all the raw materials in marine shrimp, seabass and seabream and tilapia.

Plant meals (soybean meal/canola meal/rapeseed meal)

Globally, plant proteins are typically lower in mycotoxin contamination due to their growing seasons when the mycotoxin exposure levels are lower. Although this is of less a concern, the increased inclusion of these ingredients will enhance the overall risk in aquafeed. Research shows that the synergistic effect of multiple mycotoxins can be particularly harmful.

The most prevalent form of mycotoxin is DON, with some emerging mycotoxins from *Fusarium*. In the present survey, it was observed that the plant meal samples (i.e., soybean meal, canola meal and rapeseed meal) were contaminated with significant amounts of DON and zearalenone (Table 2). Looking into the multi-mycotoxin risk, the samples contain the mycotoxin levels from low risk to high-risk in all the tested species. About 14.3% of plant meal samples pose a high risk to shrimp, and 8.6% of samples pose a high risk to freshwater and marine fish (Figure 2). Although the general inclusion rate of plant meals in aquafeeds is about 40–50%, the risk will be diluted from high level to moderate levels and it will still cause significant performance issues. So regular screening of plant meals for mycotoxins and the implementation of other mitigation plans are necessary to reduce the risk of toxicity in the first place.

Average concentration of mycotoxins above LOQ		
Mycotoxins	Average (ppb)	Maximum (ppb)
Aflatoxins	<3	5
Ochratoxin	33	119
Deoxynivalenol	<300	1000
T2/HT2 toxins	<50	<LOQ
Fumonisins	<250	780
Zearalenone	144	276
Ergot toxins	not analysed	

Table 2. Average concentrations of mycotoxins in plant meals.

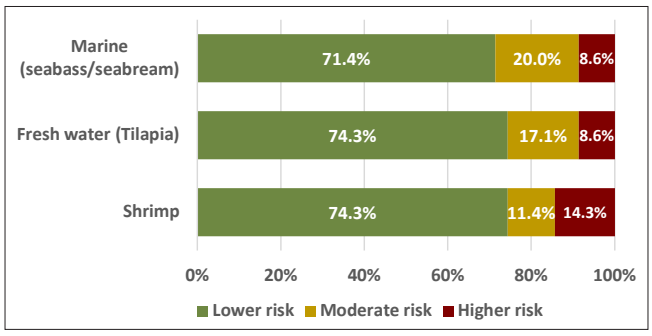


Figure 2. Percent of plant meal samples at lower, moderate or higher risk.

Bran and wheat flour

Wheat flour and rice bran are often used in aquafeed as an energy source and gelatinising material to enhance pellet stability. RAPIREAD analysis of these samples revealed the presence of DON at significant risk levels and other mycotoxins at lower risk levels (Table 3). However, for the cumulative mycotoxin risk, REQ is lower to moderate for freshwater and marine fish, and 6.1% of samples are high-risk for shrimp (Figure 3).

Average concentration of mycotoxins above LOQ		
Mycotoxins	Average (ppb)	Maximum (ppb)
Aflatoxins	6	9
Ochratoxin	<2	6
Deoxynivalenol	<300	410
T2/HT2 toxins	<50	<LOQ
Fumonisins	<250	988
Zearalenone	<50	63
Ergot toxins	not analysed	

Table 3. Average concentrations of mycotoxins in bran and wheat flour. LOQ= Limits of quantification.

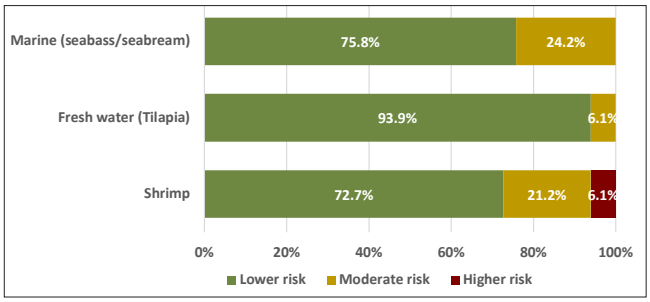


Figure 3. Percent of bran and wheat flour samples at lower, moderate or higher risk.

Corn by-products (DDGS/CGM)

Globally, corn poses a significant mycotoxin risk. Most of the time, the greatest concern is aflatoxins, but *Fusariums* present an equal and even greater risk. The present survey revealed the presence of DON and zearalenone at high-risk levels (Table 4). The cumulative toxin effect was more alarming: about 88–94% of samples are at high REQ levels across the tested species (Figure 4). Although aquafeed millers seldom use complete grains in fish and shrimp feeds, corn by-products are often included in significant quantities. When we mill these different by-products in the manufacturing process, we decrease mass, but the mycotoxins are concentrated in a lower mass, causing risks to the animals.

Average concentration of mycotoxins above LOQ		
Mycotoxins	Average (ppb)	Maximum (ppb)
Aflatoxins	14	75
Ochratoxin	5	8
Deoxynivalenol	2,403	4,400
T2/HT2 toxins	<50	65
Fumonisins	1,347	6,149
Zearalenone	485	694
Ergot toxins	not analysed	

Table 4. Average concentrations of mycotoxins in corn

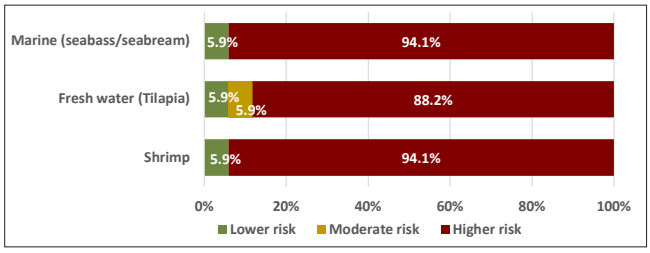
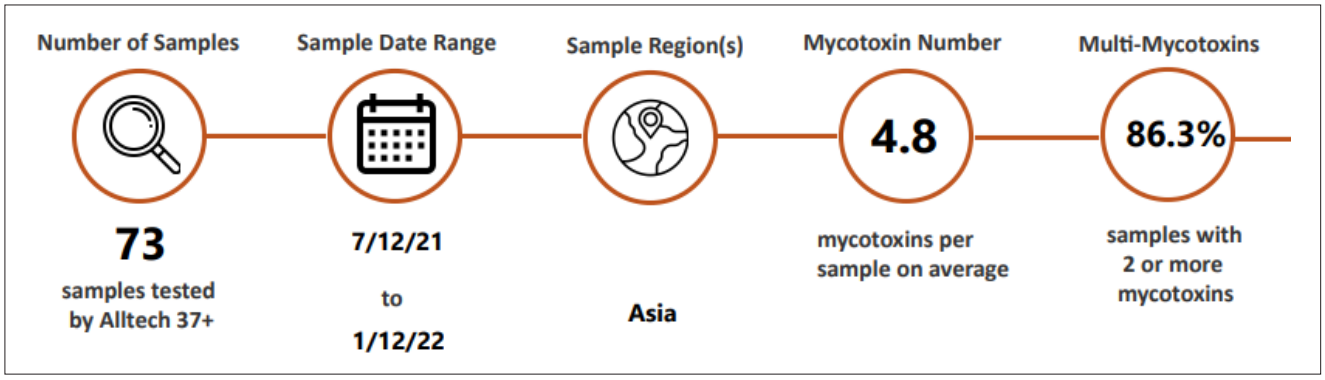


Figure 4. Percent corn gluten meal/DDGS samples at lower, moderate or higher risk.



Finished feed

About 73 aquafeed samples were analysed for 54 mycotoxins using Alltech 37+ technology. On average, each sample contained 4.8 mycotoxins, and about 86.3% of feed samples contained more than two mycotoxins (Figure 5).

In shrimp feeds, the risk was high due to a broad range of toxins, but type B trichothecenes stood out. Marine fish feeds have a lower overall risk, which was primarily from type B trichothecenes, zearalenone and fusaric acid. The lower risk was probably due to the lesser use of plant materials in marine fish feeds. Freshwater fish feed samples were recorded with high REQ from aflatoxins, type B trichothecenes and ergot toxins (Table 5). Little is known about the impact of ergot toxins in aquaculture, while in other species, ergot impacts distal blood flows. About 96% of shrimp feed samples contained at least one mycotoxin. Overall, type B trichothecenes in finished feed (Figure 5) and DON (a type B trichothecene) in the raw materials were of concern across the species tested (Figure 1). This clearly indicates the mycotoxin threat was from the raw materials.

Average Assessment for Performance Impairment for Aqua - Shrimp (100% Inclusion of Finished Feeds)

Mycotoxin Group	Average Based on Inclusion, ppb	Lower, ppb	Moderate, ppb	Higher, ppb
Aflatoxin B1	1.2	5	10	20
Aflatoxins, Total	1.8	5	10	20
Ochratoxins/Citrinin	2.3	50	100	200
Type B Trichothecenes	534.4	50	100	200
Type A Trichothecenes	0.0	15	30	60
Fumonisins	209.5	750	1500	3000
Zearalenones	54.4	50	100	200
Fusaric Acid	153.4	500	1000	2000
Emerging Mycotoxins	5.5	500	1000	2000
Other Penicillium Mycotoxins	0.0	25	50	100
Other Aspergillus Mycotoxins	0.6	20	40	60
Ergot Toxins	0.0	50	100	200
REQ	63.3	5	10	20

Average Assessment for Performance Impairment for Aqua - Seabass/Seabream (100% Inclusion of Finished Feeds)

Mycotoxin Group	Average Based on Inclusion, ppb	Lower, ppb	Moderate, ppb	Higher, ppb
Aflatoxin B1	0.0	5	10	20
Aflatoxins, Total	0.0	5	10	20
Ochratoxins/Citrinin	0.0	20	50	100
Type B Trichothecenes	61.5	250	500	750
Type A Trichothecenes	0.0	50	100	200
Fumonisins	19.3	2500	5000	10000
Zearalenones	9.4	75	150	300
Fusaric Acid	43.0	500	1000	2000
Emerging Mycotoxins	0.0	500	1000	2000
Other Penicillium Mycotoxins	0.0	40	70	100
Other Aspergillus Mycotoxins	0.0	20	40	60
Ergot Toxins	0.0	50	100	200
REQ	2.5	5	10	20

Average Assessment for Performance Impairment for Aqua - Carp (100% Inclusion of Finished Feeds)

Mycotoxin Group	Average Based on Inclusion, ppb	Lower, ppb	Moderate, ppb	Higher, ppb
Aflatoxin B1	8.5	25	50	100
Aflatoxins, Total	8.5	25	50	100
Ochratoxins/Citrinin	0.4	50	100	200
Type B Trichothecenes	666.2	250	500	1000
Type A Trichothecenes	0.0	50	100	200
Fumonisins	303.8	2500	5000	10000
Zearalenones	59.8	75	150	300
Fusaric Acid	109.0	500	1000	2000
Emerging Mycotoxins	6.3	500	1000	2000
Other Penicillium Mycotoxins	2.4	40	70	100
Other Aspergillus Mycotoxins	0.7	40	60	80
Ergot Toxins	51.2	50	100	200
REQ	130.8	25	50	100

Table 5. Mycotoxin contamination in shrimp feed, marine fish feed -seabass/seabream and freshwater fish feed -carp.

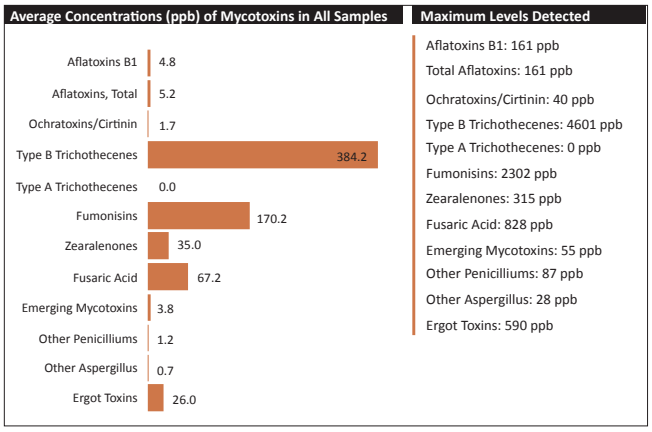


Figure 5. Mycotoxin contamination in all finished feed samples.

Farmers in Asia are facing serious production challenges, including those from masked mycotoxins in feeds. Many experimental studies revealed the adverse effects of mycotoxins on shrimp and fish health. In a laboratory experiment, when juvenile whiteleg shrimp (*Litopenaeus vannamei*) were fed with diets containing 250–1,000ppb of DON, weight gain decreased with the increasing dietary DON levels (Xie *et al*., 2018). Survival was lower in shrimp fed with high levels of DON-contaminated wheat flour. Intestinal mucosae and the microstructure of intestinal epithelial cells were harmed by dietary DON (Xie et al., 2018). Also, exposure of whiteleg shrimp to T-2 toxin significantly decreased specific growth rate and weight gain. T-2 toxin damaged the hepatopancreas in a dose-responsive manner (Qiu et al., 2016). Exposure of tilapia (*Oreochromis niloticus*) to increasing T-2 toxin doses significantly decreased the survival rate, weight gain and hepatosomatic index, and induced liver cell and myofibre damage (Deng et al., 2019).

Based on a review article from Koletsi et al. (2021) on mycotoxins in European aquafeed stuff, 80% of the wheat samples were contaminated with mycotoxins. The same was found in 95% of corn and 87% of soybean meal samples. *Fusarium sp.* mycotoxins are the most common and dominant among the raw materials. There was also a high level of mycotoxin co-occurrence — from 63–88% of samples. In fish feeds, the frequency of mycotoxin co-occurrence was from 36–55% for fusaric acid, DON and fumonisin B_1. DON is the most important mycotoxin in European aquaculture. In a meta-analysis on the effects of DON on fish species, DON reduces feed intake exponentially by 13.2% and growth by 16.5% (Koletsi *et al*., 2021). In Koletsi's wet laboratory experiments with rainbow trout, they found that the responses were more severe; feed intake dropped by 18.8% and growth by 20%. A histopathological study revealed clear liver necrosis and haemorrhage upon feeding with a DON-contaminated diet for one week.

Exposure of juvenile turbot (*Scophthalmus maximus*) to DON at 3ppm significantly decreased weight gain, specific growth rate and feed efficiency ratio and reduced levels of IgM and complement four concentrations in serum. DON also decreased the abundance of potential helpful bacteria and increased the abundance of potential pathogens in the intestine (Wang et al., 2021). The addition of Mycosorb® (yeast cell wall extract) at 0.2% and 0.4% to the DON-contaminated diets significantly improved growth performance and immune response and enhanced the intestinal health of turbot (Wang *et al*., 2021). In another experiment by Yang et al. (2020), turbot juvenile exposure to aflatoxin B1 at 500ppb significantly hampered the immune system and health. However, supplementation with Mycosorb at 0.2% and 0.4% levels restored the immune response, relieved adverse effects in the liver, lowered the AfB1 residues in turbot tissues, promoted intestinal microbiota diversity and lowered the abundance of potential pathogens.

Conclusion

The present survey reinforces the risk of multiple mycotoxins from plant raw materials in shrimp, marine and freshwater fish. Mycotoxins in plant material typically accumulate during crop harvest due to adverse weather conditions, such as unseasonal rains, moisture, heat and drought. Effective mycotoxin management is about seeing the whole challenge — from the farm to the feed mill — and from risk assessment to feed management.

The Alltech® Mycotoxin Management program provides several solutions to mitigate the threat. The Alltech 37+ analytical laboratory conducts an ISO-accredited procedure that analyses 54 mycotoxins in a sample using UPLC-MS/MS to accurately determine mycotoxins with the highest level of sensitivity.

Guideline limits for mycotoxins in aquatic species to reduce negative effects on health and performance was published in Aqua Culture Asia Pacific November/December 2020, pages 54-58.

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Dr Sudhakar V. S. Govindam is with Alltech Biotechnology Pvt Ltd, Kodihalli, Bangalore, India.
Email: sgovindam@alltech.com

Henry Wong is with Alltech, Malaysia.
Email: hwong@alltech.com

Asia's aquafeed players battle with rising costs

Rising feed raw material prices continued from 2021 but with new challenges- escalating wheat prices and inflationary pressures in 2022

Feeding cobia in cages

These last two years (2020 and 2021) have been difficult times for Asia's aquafeed players with uncertainties and since September 2020, unprecedented rises in costs of major feed raw materials, namely soybean meal and corn. A detailed report "Is there a crisis in the works for Asia's aquafeed players?" was published in issue May/June 2021, p28-34). In this review, we continue to follow the trends in 2021 up to May 2022.

In summary, the battle continues as the challenges faced in 2020 and early 2021 remain unabated. However, added to this is the new dimension since March 2022 - the effect of the Russia-Ukraine war on global wheat supplies, rise in energy and fuel costs and onset of inflationary pressures. In preparation for this review, we asked some industry players on their strategies following the rise in feed raw material costs as well as their views on functional feeds, automation and outlook for 2022.

Rise in feed raw material prices

Aquafeed players singled out peak prices with soybean meal (SBM) throughout 2021. Prices rose even higher to USD521.9/tonne in early March 2022, up 64% from that in October 2021. From the first week of March 2022, the price per tonne of wheat surged 80%, compared to that of the past 12 months. As a comparison, in November 2021, wheat prices were around USD311.50/tonne. In May 2022, corn prices rose 29% YTD (Market Insider). In India, Dr Ajay Bhaskar, Nutritionist at IFB Agro Industries, said, "SBM prices were at all-time high in 2021 at USD1.5/kg. Luckily now it is lower at USD1/kg. We were in a better situation when the government allowed imports of SBM in 3Q 2021."

In 2020, aquafeed millers were able to support the farming system, by extending credit to farmers during the lockdowns, when farmers could not sell their harvests. But since late 2020, a different picture emerged when aquafeed millers themselves are also suffering with high costs of raw materials and rising production costs. This is reflected in Indonesia when a leading aquafeed miller known for its CSR (corporate social responsibility) activities decided to not aggressively pursue sales. A company source said, "Within this pandemic we have restrained from increasing feed prices with farmers facing cash flow problems. Recently, by not changing formulations and incurring significant cost increases of more than 10%, we needed to increase feed prices more than once in 2021 for fish feed and once for shrimp feed."

Production trends in 2021

Some industry players gave their take on aquafeed production in 2021. Dong Qiufen, Guangdong Nutriera Group, quoted data from the China Feed Industry Association which gave the growth in aquafeed production in **China** at 8% in 2021 to 22.9 million tonnes. This is higher than the 21.7 million tonnes published in Alltech's annual agrifood survey. However, another estimate on growth was only 5%.

In China, the bulk of aquafeed production in 2021 was freshwater fish feed (16 million tonnes). Production of marine fish feed ranged from 2 to 2.5 million tonnes and shrimp feed was 1.1 to 1.5 million tonnes. Industry players said significant changes were the result of higher demand for feed for high value freshwater fish like the snakehead and largemouth bass. Feed demand also rose

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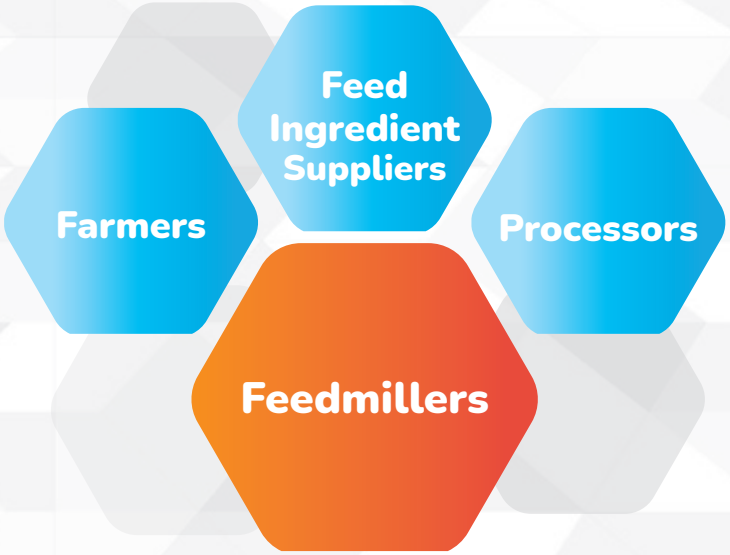

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"Some feedmills increased feed prices and replaced use of expensive raw materials and feed additives. They did not change specifications but reformulated," said Dr Yufan Zhang, Alltech China Aqua Business Development Manager.

for the pangasius, rainbow trout, Japanese seabass and shrimp. "Demand came from the expansion of existing farms and production increases because of higher market price, new aqua technologies and intensive culture," said Zhou Enhua, Aquaculture Technical Manager, US Soybean Export Council.

The estimate for total aquafeed production in **India**, which excludes the production from small feedmillers and toll milling, ranged from 2.0 to 2.37 million tonnes in 2021. Shrimp feed production fared better with the resurgence in shrimp demand in world markets. In 2021, India's farmed shrimp production increased to 920,000 tonnes, (Ravi Kumar Yellanki, Vaisakhi Bio-Marine (P) Ltd, pers comm, May 2022). Shrimp feed demand rose by 7-10% in 2021 to 1.35 million tonnes and demand was also driven by the conversion of fish farms to farming vannamei shrimp at low salinity.

Industry players in India diverge on the increase in fish feed production in 2021, from a mere 1-2% to as high as 10% (from 650,000 to a million tonnes). The reason was fluctuating fish prices and higher feed prices which lowered demand but in north India, a higher feed demand was linked to the expansion in fish production. Interestingly, 10,000 tonnes of marine fish feed were produced in 2021, a breakthrough as for many years, marine fish production was too small and fragmented to attract the interest of local players.

In **Indonesia**, total aquafeed production in 2021 was estimated at 1.62 million tonnes where 423,500 tonnes of shrimp feed were for a production of 445,000 tonnes of both vannamei and monodon shrimp, according to data from the Indonesian Feedmills Association or GPMT. Fish feed production dropped slightly (2%) to 1.23 million tonnes, versus 1.25 million tonnes in 2020. Most of the feed production was for freshwater fish; tilapia, common carp and catfish (both *Clarias* and pangasius). Small volumes of marine fish feed were for groupers and Asian seabass farming, where the production in 2020 was only at 26,182 tonnes (Rokhmin Dahuri, ICAI, 2021). At the International Conference on Aquaculture in Indonesia (ICAI, 2021), the Catfish Association Indonesia (APCI) said that expensive commercial feeds curtailed pangasius production. Floating pellets cost IDR8,500 to IDR14,500/kg, depending on brands and protein content, whereas ex-farm fish prices fluctuate from IDR9,000 to IDR25,000/kg depending on regions.

Total aquafeed production in **Vietnam** declined 15% in 2021 to 3.42 million tonnes. Shrimp feed production increased slightly to 930,000 tonnes for both vannamei and monodon shrimp. The ratio of production is generally 70:30 (vannamei: monodon). Fish feed production decreased 28% to 1.05 million tonnes and pangasius feed production declined to 1.4 million tonnes. Industry reported a production of 45,000 tonnes of marine fish feed in 2021.

Jeff Chuang Jie-Cheng, General Manager of Sheng Long Bio-Tech International, reflected, "Demand for all fish feeds decreased compared to 2020 due to low fish prices. As cost of feeds increased continuously, distributors minimised credit for farmers. Some farmers did not stock, and some reduced stocking density and also feeding rate. However, we attributed the slight increase in demand for shrimp feeds to successful production in lined pond models."

The estimates presented by the industry in **Thailand** showed an increase of 4.5% to 1.1 million tonnes of aquafeeds in 2021. Shrimp feed production was 464,000 tonnes. Fish feed production also rose to 540,000 tonnes and marine fish feed (mainly for seabass farming) rose to 55,380 tonnes.

In the **Philippines**, industry estimated that total aquafeed production probably declined by 5-10% in 2021. Farmed fish and shrimp are mainly for domestic markets and the pandemic continued to slow down purchasing power of consumers. The logistics challenges and increases in feed prices forced farmers to wait and see, harvesting when there is market demand. It was expected that higher pork prices would increase the price point of farmed fish, but this did not happen. Local production of shrimp feeds was estimated at only 30,000 tonnes in 2021, justified by the fact that monodon shrimp production is mostly extensive and uses small volumes of feeds. There is a large volume of imported shrimp feeds from three leading multinationals in Vietnam and one from Thailand. In 2021, logistics was a pain point for feed imports since the shelf life of shrimp feeds is only 6 months.

Managing formulation costs in 2021 and 2022

With higher cost for major raw materials for fish feed, mainly SBM, plant protein meals and soy oil in China, feedmillers saw their formulation cost increasing up to 15-20% for fish feeds, depending on the species. In Guangdong, shrimp feed formulation costs rose 10-15%. To overcome these costs increases, Dr Yufan Zhang, Alltech China Aqua Business Development Manager said, "Some feedmills increased feed prices and replaced use of expensive raw materials and feed additives. They did not change specifications but reformulated."

Zhou said, "Some feed millers and fish producers shared the price increase of ingredients. While some feed millers changed formulations, and lowered specifications, fish farmers exercised control in feeding rations. USSEC encouraged farmers to lower feed conversion ratios (FCRs) through better feeding practices and feed management."

Due to continuous hikes in raw material prices (mainly SBM, wheat flour and fishmeal) industry in Vietnam cited 15% increase in production cost for shrimp feed and 20% for fish feed. Vinij Tansakul, Consultant said, "Since last year, Thai feed millers face high prices for imports of raw materials but also need to pay import tax at the same rate which, therefore increase their production costs. In 2022, there was some serious supply issues to the factory."

In India, formulation cost increases ranged from 7% to 35% for shrimp feeds. It was INR 2-3/kg for fish feed. In shrimp feed, cost increases were mainly due to higher prices for SBM, fishmeal as well as wheat flour; in fish feed, it was deoiled rice bran (DORB), rice bran, corn, dried distillers grains and solubles (DDGS) and deoiled groundnut cake. Ajay said, "Nutritionists and formulators reformulated to balance given feed specifications. In 2021, we saw that many farmers opted to use low-cost feeds and lower specification feeds. They fed fish with the economy brands with 20-24% crude protein (CP) and 3% lipid instead of premium feed with 28% CP and 4% lipid. In some places, farmers also stopped using pelleted feeds and shifted to feeding low cost DORB and mash feeds. Furthermore, we saw that the market prices of fish dropped for a longer period during the second wave of the pandemic."

Seshu Akkina, COO, said that at Deepak Nexgen Feeds, they mitigated high increases in raw material costs with a well-planned procurement system; they also focused on reducing waste and carried out some cost cutting.

Relative to the above, a regional feedmiller cited only 2-10% increases in formulation costs which were mainly due to costs of SBM, scarcity of animal meals from the EU and high freight costs. In part, costs were well managed by optimising feed ingredients and with a strong local supply chain.

"We waited until we had zero profits and began to raise prices to survive during the second crop in 2021," - Dr Ajay Bhaskar, Nutritionist at IFB Agro Industries

Increasing feed prices

Inevitably, during this period, throughout Asia, whether for fish or shrimp feeds, feed millers took to increasing feed prices, such as once at 1.5% in 2021 and perhaps again in 2022, said industry in the Philippines. Shrimp feed prices average USD1.2/kg in 2022 but added to higher production costs as farmers also faced 7% increases in post larvae prices.

"Some feed millers and fish producers shared the price increase of ingredients. While some feed millers changed formulations and lowered specifications, fish farmers try to control feeding rations," said, Zhou Enhua, Aquaculture Technical Manager, U.S. Soybean Export Council.

In April, Chairman of GPMT, Indonesia, Deny Mulyono said that in 2022, influenced by the global trends in feed ingredient prices, aquafeed millers made the necessary price adjustments for fish and shrimp feed which vary according to the feed formulation (kompas.id) The increase in feed prices was due to the increase in the price of raw materials of feed, both imported and local. He added that the difficulty in purchasing raw materials also triggered competition for raw materials with other feed producing countries. An Indonesian shrimp farmer said that increases of IDR500/kg was followed by another IDR700/kg increase, all within one month in 2022. However, he added that shrimp feed prices were still below USD1.15/kg.

The Department of Fisheries, Thailand, controlled feed prices but in 4Q 2021 allowed a 3-5% price increase. Tansakul said, "Feed millers raised retail prices 3-4 times in 2022. I also expect shrimp feed volumes to be 7-10% less than that in 2021."

Industry sources in China were unanimous on feed price increases - CNY300-800/tonne depending on fish species. In the case of shrimp and largemouth bass feeds, the range was CNY400-1,000/tonne, which also depended on the area and competition among players. Increases since 2020 were estimated at 5-11% for shrimp feed, 7-17% for freshwater fish feeds and 5-11% for marine fish feeds. Alongside higher cost for finished feed products, the news portal, Fishfirst.cn reported that in August, in the provinces of Jiangsu, Hunan and Henan, there was higher transportation costs (with drivers needing 48 hours for PCR testing for the coronavirus, doubling freight costs) and it took 7-8 days (or more) to find a delivery truck.

In China, a September 2021 Reuters report said that an aquafeed miller raised his fish feed prices three times since May and by up to 20%. It also said although previously fish was among the cheapest sources of protein in China but in 2021 was more expensive than chicken and recently also higher than pork, alluding to the fact that rises in feed prices were linked to higher fish prices. Average wholesale prices of four freshwater fish monitored by the country's agriculture ministry jumped almost 40% from the previous year.

In India while a feedmiller quoted an increase of shrimp feed prices by as much as INR16/kg, another only gave

Vinij Tansakul, Consultant, said, "Since last year, Thai feed millers face high prices for imports of raw materials but also need to pay import tax at the same rate which therefore increase their production costs".

an increase of INR2-3/kg. It was standard at INR1-3/kg for fish feed. Ajay said, "We waited until we had zero profits and then raise prices to survive during the second crop in 2021."

Chuang commented, "In 2021, increases in raw materials were too fast and we hardly had time to deal with these new prices. As we still insist on not changing any ingredient and specification because of quality concerns, the only solution is to adjust feed prices. But as a company, we also absorb part of the cost to support aquaculture in Vietnam." Some examples of increases in feed prices were USD120/tonne for tilapia feed and USD 100/tonne for shrimp feed.

Replacing fishmeal and alternative feed ingredients

China is a leading consumer of fishmeal and fish oil. Xu (IFFO, 2021) noted the high inclusion rates of 17.5% fishmeal and 2% fish oil in shrimp feeds. In contrast, shrimp feed in Thailand contained only 12% fishmeal. High inclusion rates of fishmeal are also found in the feeds for seabass (35%), eel (45%), pompano and snakehead (25%) and largemouth bass (30%). Some recent popular alternatives as replacement for fishmeal includes single cell proteins such as ethanol *Clostridium*

Dong Qiufen , Guangdong Nutriera Group, said, "In 2022, our strategy is to promote functional feed, control costs and pay more attention to better use of raw materials."

protein but from a nutritionist's point of view, these must be cheaper than fishmeal when calculating the protein and lipid composition (Zhang, 2022). Fermented raw materials are also getting a lot of attention.

"Over the last five years, we discussed the use of *Spirulina*, krill meal and insect meals but we found that there are limitations with cost, supply and quality. Now some feed millers realise the value of these novel ingredients and are using krill meal in their shrimp feed. In the end we found that fishmeal was cheaper," said Ajay.

Rather than alternative feed ingredients, for better feed efficiency, in Vietnam, Chuang proposed the introduction of more advanced feed processing equipment to coat pellets with heat-sensitive raw materials or additives such as probiotics, vitamins and enzymes. He also recommended that farmers use automation for better feed management and autofeeders to reduce labour costs, improve FCRs and production efficiency.

Functional feeds

There is the concern on proven efficacy of functional feeds which have been in the market for some time in Asian aquaculture. Zhang believes that functional feeds will be the new direction in China, veering away from traditional feed. Sales of functional feeds have increased because of visible positive effects and farmers accepted the higher costs for these feeds. In Guangdong, Dong said that functional feeds comprise 5% of the aquafeed market mainly because of the need to manage diseases and improve farm production.

In India, various functional feeds abound such as those using Ayurveda homeopathy with plants. In the case of Deepak Nexgen, functional feeds comprised 5% of products and Seshu said that they will continue to do R&D to develop best products. Although functional feeds accounted for 2.5% of Sheng Long's feed sales in Vietnam, in 2021, with lower and unfavourable fish and shrimp prices, and higher production costs, farmers have shifted away from using functional feed and Chuang did not see any growth in sales.

A similar observation was reported in Thailand where farmers shifted away from higher priced functional feeds since feed performance did not match expectations. In fact, there was an increase in the use of low cost feeds.

Automation in feed management

There is a general agreement that automation will reduce labour costs, improve FCR, and is recommended to improve production efficiency and reduce nitrogen discharge to the environment. With acoustic autofeeders, it has been possible to achieve FCR of <1 with the better understanding on the feeding behaviour of vannamei shrimp. There are developments in data algorithms and analytics but Asia is far behind with data analysis, and local capacity needs strengthening. It is important that feed technicians understand the equipment and how the fish and shrimp adapt to feeders.

In China, aquaculture is dominated by small family farms where time feeders are adequate. However, Zhou said that autofeeders are commonly used in IPRS (In Pond Raceway Systems) with extruded feeds. Indian corporate farms are already adopting autofeeders with good results. According to them, such automation reduces feed wastage and labour; the next level is using drones for feeding and chemical applications subject to government approval.

"In 2022, our main concerns will be the high costs of production such as electricity, fuel cost and supply, and abnormal increases in raw material prices and logistics." said, Seshu Akkina, COO, Deepak Nexgen Feeds.

Outlook for the rest of 2022

Moving forward in 2022, we will find additional problems. Aquafeed millers will need to increase prices which ultimately will raise costs of production at the farm level. But there will be times when the farmer will find that ex-farm prices remain low because of supply chain disruptions. Processing plants cannot buy because the warehouse is full from a lack of containers to ship products. Today, we see this situation with the closure of Shanghai port and containers queuing along its coast, aggravating the situation of container shortage.

In China, the situation is full of uncertainties and challenges -the ongoing zero Covid policy, protection of the environment and high raw material costs cannot be compensated by the increasing numbers of seafood consumers. "In 2022, our strategy is to promote functional feed, control costs and pay more attention to better use of raw materials," said Dong. Agreeing with Dong, Zhang is not optimistic at all but expects that prices of raw materials will ease only during the second half of 2022 when global logistics are less affected by the Russia-Ukraine war. "For me it is difficult to make predictions; my goal is more towards stabilising the existing business and operations."

Ajay gave a more dire situation in India. "Recently, the Andhra Pradesh state government increased electricity tariffs for farms which means that production cost will increase. This state produces 40-50% of aquafeeds in India."

Chuang commented, "I expect 2022 to be more challenging with all the negative impacts from war, hikes in oil prices and soaring costs of ocean freight. I also expect the inefficient supply of raw materials and increasing costs to continue. Here in Vietnam, inflation is increasing labour costs. Fortunately, seafood prices and demand are increasing and therefore good for the feed market. But I predict that feed prices will rise by 10-20% in 2022. When the seafood demand is up but prices for the farmers remaining low, I predict that farmers will not wish to stock for the next crop.

"Here in Vietnam, the inflation hikes up labour costs. Fortunately, seafood prices and demand are increasing and therefore good for the feed market. But I predict that feed prices will rise by 10-20% in 2022," said, Jeff Chuang Jie-Cheng, General Manager of Sheng Long Bio-Tech International.

"Nevertheless, as a company, we will continue to look ahead. We will launch a new aquafeed plant in Vinh Long province with an annual production of 200,000 tonnes. We have also rescheduled our Malaysia aquafeed plant to start operations by 2024."

Deepak Nexgen managed to increase shrimp feed sales by 25% in 2021. "In 2022, our main concerns will be the high costs of production such as electricity, fuel cost and abnormal increases in raw material prices and logistics. We can expect more increases in raw material prices since fuel prices are increasing at rocket speed. We expect to continue growing our business at 20% growth for the next 5 years. We target shrimp feed sales of 250,000 tonnes and fish feed sales of 200,000 tonnes in FY2022. Our goal is to become India's second largest aquafeed company by FY 2022-23. We also plan to set up a processing plant and export shrimp in FY2023," said Seshu.

In terms of new directions, feed producers will continue to optimise formulation to adapt and promote cost-effective diets. "We expect that producers will absorb and accept price increases but the Philippines feed market is expected to be saturated and will not grow significantly until an export market is established for its shrimp production. As a feed supplier, we will continue to adapt our strategy to deliver premium quality products with optimised nutrition and offer products at a much better price point," said Mark Rowel Napulan, Asia Sales Manager at Zeigler Bros., Inc

We expect that producers will absorb and accept price increases but the Philippines feed market is expected to be saturated and will not grow significantly until an export market is established for its shrimp production- Mark Rowel Napulan, Asia Sales Manager at Zeigler Bros., Inc

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"Fish-Free" feed for largemouth bass is feasible and economically viable

New study reports that fishmeal, fish oil-free feeds deliver excellent growth, survival, feed conversion and fillet quality

In the study, largemouth bass (LMB) Micropterus salmoides of ~15.2g initial weight, was fed one of the five experimental, and a fishmeal/fish oil control diet and two commercial (Xinxin, Coppens) LMB feeds for 10 weeks. Fish were dispersed into 24, 110L aquaria at 20 fish/tank) configured as a recirculating system. There were triplicate treatments with 60 fish/diet.

Total replacement of fishmeal and fish oil in largemouth bass feed is both feasible and economically viable, according to a new study published in the journal *Aquaculture Research*.

The fish fed experimental feeds without fishmeal or fish oil also had higher DHA-to-EPA ratios than those fed commercial feeds, with algae oil having the highest ratio. Consumers ultimately benefit from these higher amounts of heart and brain healthy DHA and EPA from eating the fish.

The vast majority of the farm-raised largemouth bass is farmed and consumed in China—an estimated 432,000 tonnes in 2018 according to the China Fishery Statistics Yearbook. As the world's largest producer of farmed fish, China is working toward more sustainable farming practices nationwide. Largemouth bass, which is native to North America, was first introduced into mainland China in 1983 and today is a major freshwater aquaculture product throughout the county.

"This will also come as good news for fish farmers in China at a time when consumers are shifting their appetites toward high-value species like largemouth bass that consume large amounts of fishmeal and fish oil," said Ewen McLean, lead author of the study and principal at Aqua Cognoscent. "Switching to locally sourced, and often cheaper feed ingredients could help put more money in the pockets of fish farmers."

The price of fishmeal has increased 3.4-fold over the last 20 years, and the present-day cost is around USD1429/tonne. On the other hand, the price for soybean meal, an often-used substitute for fishmeal in aquafeeds, has risen 2.8-fold over the same timeframe and is roughly half the price according to Index Mundi. Alternatives to fish oil, such as soybean and canola oils are on average less expensive as well.

During the 10-week feeding trial conducted in a recirculating aquaculture system at Texas A&M, McLean and colleagues compared weight gain, survival rates, feed conversion ratio and fillet quality of fish fed fishmeal, fish-oil free experimental diets against two commercial feeds (Huifu, Xinxin Tian'en Company, Zhejiang Province, PR China and Alltech Coppens, Leende, The Netherlands), specifically designed for juvenile largemouth bass (*Micropterus salmoides*). The fishmeal component of experimental diets was replaced using poultry by-product meal and soy protein concentrate. One experimental diet contained fish oil whereas in others, fish oil was replaced with canola, flax and/or algal oil or combinations thereof.

At the end of the trial all fish fed the experimental fishmeal and fish-oil free diets had similar weight gain and survival rates matching those fed the Xinxin commercial feed. The Coppens commercial feed had the lowest growth and survival rates. The experimental diets also had excellent feed conversion ratios.

According to a 2018 study in *Nature Sustainability* if current use of fishmeal and fish oil by the animal feed sectors remain the same, forage fish populations will be overextended by 2050, or before. Commercially valuable species such as salmon, cod and tuna, as well as marine mammals and seabirds depend on forage fish in the wild. Since over 50 percent of seafood is farmed, the variety of seafood on consumers' plates could shrink without innovation in "fish-free" feeds, since they rely on wild-caught resources.

This study is a step towards removing the supply chain bottlenecks by testing more available and sustainable ingredients that will make seafood available into the future.

The study was supported by the F3 – Future of Fish Feed's Feed Innovation Network. The F3 - Future of Fish Feed is a collaborative effort between NGOs, academic institutions, and private partnerships to accelerate the commercialisation of innovative, substitute aquaculture feed ingredients to replace wild-caught fish. The study is available as open access. https://f3fin.org

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Strategic alliance on India's first homegrown feed for shrimp larvae

Signing the MOU were Dr K.P. Jithendran, Director, ICAR-CIBA and Shri V.R. Sharma, Vice-President, Coastal Corporation Ltd. Looking on are Dr Joykrushna Jena (second row) and Dr K. Ambasankar (right).

Quality larvae feeds are the central element for successful shrimp hatchery operations. At present the larvae feeds used in India are all imported and expensive. In this context, industry in India says cost-effective indigenous feeds for shrimp larvae is the need of the hour for sustainable aquaculture.

Over the last five years, focussed research at the Central Institute of Brackishwater Aquaculture, Indian Council of Agricultural Research under the Ministry of Agriculture and Farmers Welfare (ICAR-CIBA) has resulted in the development of Shrimp Larvi^{Plus}. This feed has been tested and demonstrated for its effectiveness in various shrimp hatcheries in Tamil Nadu and Andhra Pradesh. This is India's first indigenous feed for shrimp larvae.

In May, ICAR-CIBA formed a strategic alliance with M/s Coastal Corporation Ltd, Visakhapatnam, Andhra Pradesh, under the "Make in India" program for the manufacture of this shrimp larvae feed. A memorandum of understanding (MoU) was signed in the presence of Dr J.K. Jena, Deputy Director General (Fisheries), ICAR, New Delhi. Jena during his address appreciated the scientists and highlighted the necessity for promoting this shrimp larvae feed.

According to Dr K.P. Jithendran, CIBA Director, this effort will undoubtedly improve the economics, contribute to innovation and growth and encourage sustainability and competitiveness in the aquafeed sector in the longer run. He also expressed his wish for a long-lasting and beneficial journey and for both parties to share experiences. Shri V.R. Sharma, Vice President, Coastal Corporation Ltd. narrated his three decades of hatchery and farming experience and shared the encouraging trial results obtained with CIBA's shrimp Larvi Plus as well as his intention to take this technology not only within India but to a global level.

Dr K. Ambasankar, Principal Scientist and team leader for feed technology, acknowledged the significance of this MoU and outlined the genesis of this initiative. He stressed that this technology would benefit the aquaculture sector in the long run. On the current situation with shrimp larvae feeds in India, Ambasankar said, "There are umpteen brands of imported shrimp larvae feeds available in the market. However, quality varies from brand to brand. The cost also varies from INR1000/kg to as much as INR3,000/kg (USD12.9 -USD38.8/kg). This high cost of larvae feed is coupled with the difficulties in importing particularly during this Covid-19 pandemic. Then, there is the additional import duty. Therefore, there is a requirement of an indigenous larval feed. Our main objective is to provide a quality and cost-effective feed available for hatcheries situated all over India."

He told AAP that the R&D trial has been completed. Testing in the commercial hatcheries in India gave encouraging results. "The results showed that this feed is on par with the best feed available in the market. The test feed has been prepared in our pilot scale feed mill. Based on these test results, Coastal Corporation Ltd will commercialise the technology and the feed is expected to be commercially available by 2023. However, if anyone is interested to get the sample tested internationally, we can provide the feed sample.
www.ciba.res.in

Game changer in freshwater prawn farming

With genetic improvement of broodstock and mastering hatchery technology, GK Aqua is set to mass produce all male post larvae, bringing a new outlook on freshwater prawn farming in Malaysia

By Zuridah Merican

Generation 4 Malaysian giant freshwater prawn broodstock at GK Aqua, Malaysia

It has been six years since Giva Kuppusamy, CEO, founded GK Aqua (GKA), a Malaysia-based biotechnology startup to revive farming of the giant freshwater prawn *Macrobrachium rosenbergii* or udang galah in Bahasa Malaysia. With low supply, there is a lot of interest - Malaysians are sentimental over this freshwater prawn. There is the Malay cuisine of cooking them in curries and the high-end Chinese Sang Har noodle dish. With aquaculture production declining to only 205 tonnes in 2019, 90% of demand (2,700 tonnes, DOF, 2019) was fulfilled with imports from India and Bangladesh.

GKA has BioNexus status after securing investments of up to MYR3.5 million (USD0.8 million) from Malaysia government funds - Cradle, PlatCOM Ventures and SME Corp - for its initial phase; genetic improvement of the local stocks and to scale up hatchery technology for mass production. To reach an optimal number of larvae from broodstock, the bottleneck was a lack of understanding on maturation diets for the freshwater prawn. It is essential to have high survival rates along the supply chain - during the grow-out of post larvae as broodstock, spawning efficiency, nutrition and mastering hatchery technology.

"Our initial years were difficult. There is the technology of rearing the post larvae to mature broodstock over 4 months. The rule of thumb was that each 40-50g broodstock will result in 20,000 larvae/spawn, assuming a 40% survival rate. With five spawnings per year, we can expect 50,000 post larvae/year calculated at 50% survival rate from larvae to post larvae (PL10-15)," said Giva as he recounted the early years of this startup.

"Getting the hatchery technology right was a steep learning curve for the team. We needed volumes or farmers would be giving up on us. This happened in 2018 when our survival rate in the hatchery averaged only 1-2%. This business requires a lot of will power but GKA is ready to overcome both technical and business hurdles."

From 2018 -2021, the focus was to improve broodstock grow-out and survival rates of larvae to post larvae with the help of experts from Thailand and Vietnam, respectively. Feeding broodstock with bloodworms and broodstock diets over 5-6 days yield 40-50% berried spawners. On their own, the team also learnt by trial and error, several critical requirements such as 200ppm alkalinity and 50ppm magnesium to push for more moults and speed post larvae growth.

The breakthrough was in 2020 when it achieved mass production, stocking 150 larvae/L and consistently obtaining 50-60% survival rates. "Overall, our average survival rates gradually reached 30% which is an industry standard with wild broodstock. All the above depend on using quality albeit costly larval feeds and high crude protein vannamei and black tiger shrimp feeds," added Giva.

GKA has established itself as the only supplier of all male post larvae and juveniles in the country. "As a newbie in this industry, we need to continuously secure the trust of farmers, especially among the demanding first-generation industry players. We work hard to gain the trust of existing farmers and new entrants. Farmers trust us to supply all male post larvae/juveniles (guaranteed more than 90% all male) in each consignment. Also in 2018, we had a situation where mixed sex post larvae were distributed, which was disastrous for us."

Reinventing the wheel for genetic improvement

Genetic selection of local populations to produce all male populations was always in the plan for GKA. This was possible in 2018 when it received a grant of MYR864,000 (USD216,000) from PlatCOM Ventures. "We know that the demand is there. In the last 3 years, we have proven that farming of all male populations has several advantages.

Giva Kuppusamy (CEO, centre right) and his team of researchers and technical staff. At centre left is Dr Bey-Hing Goh, who is working on a bacterium from mangrove environments as probiotics at Monash University, Malaysia.

Marketable size is achieved in 4 months versus 9 months in mixed sex farming and market size is three times larger. Without the need to separate males and females, harvesting can be completed in a single day. Overall, farms report 300% more yield and higher prices (USD5/kg vs USD30/kg). Therefore, I believe that home grown selective breeding will help the industry in Malaysia progress."

GKA worked with Xelect, a UK based specialist genetics and breeding management company to collect samples of local freshwater prawn populations, which are of two variants. Xelect developed SNP panels for the founder stocks. In 2021, GKA in collaboration with Deakin Genomic Institute, Australia, concluded the complete genome sequencing for males and females of one variant which are now used as the founder stock. "We have deposited this genome sequence at NCBI (National Centre for Biotechnology Information) scheduled for release in four years. We worked on the assumption that published sex markers are population specific. Our breakthrough was in locating the sex markers for both males and females of our founder stocks from this Malaysian variant. We will patent the sex and population specific markers which we are working on," said Giva.

Back in 2006, research showed that reversal from males to females can be triggered by the removal of androgenic glands at an early stage. On grow-out to broodstock and after mating with normal males, the result is an almost all male population (Rungsin et al., 2006). GKA's strategy was to disrupt the function of the androgenic gland. But first it had to do genome sequencing for the gland and with the isolation of the protein, GKA developed an analogue for injections of post larvae to be grown as broodstock.

Giva explained that the critical period when the transcription of the androgenic gland takes place randomly is between PL15-PL30. "The injection process is time consuming. Daily, the team injects 2,000 to 3,000 PL15 per day. We are now testing on the dosage and number of doses especially since we have international projects. At PL5 we cannot phenotype and after injection we can then do phenotyping after 2 months and validation using sex markers. We understand that we cannot achieve 100% all males. As long as we inform farmers that we supply only 90% all male post larvae, both parties will be happy," added Giva. "What is important is maintaining genetic vigour. We mate our generation 4 neofemales from our founder stocks with local domesticated males from another variant at a ratio of 500:100 and after 15 days we collect the larvae."

An extension to this biotechnological achievement is pathogen free stocks. "This is fundamental in seed production for the farmers to have better growth and without threats of pathogens. Therefore, we screen all post larvae with PCR test for white tail disease (WTD) caused by extra small virus (XSV) and *M. rosenbergii* nodavirus (MrNV) to ensure that we only supply pathogen free stocks. In house, we test all broodstock in batches by looping the DNA samples for these two diseases. Once positive, we will destroy all male broodstock but as neofemales are a cost for us, we retest them individually," added Giva.

Expansion for more capacity in post larvae production

Each production cycle is 30 days. In the case of the *Macrobrachium*, the metamorphosis of all larvae to PL10 stage is gradual and it takes 26 days for all to reach PL10-PL15. Then, there is acclimation from 15ppt to 5ppt over 4 days (instead of 24 hours) for final sales to farmers. In comparison, in wild broodstock, for all larvae to reach PL10, takes 45 days.

In 2020 during the pandemic, GKA moved to a larger 6 acres (2.4ha) premises of a former indoor grouper farm in Bukit Pelanduk, Negri Sembilan. Indoor hatchery tanks for larvae and post larval rearing and outdoor live feed culture facilities were built. It added more post larvae rearing tanks as well as tanks to hold marketable prawns for its online retail sales and an outdoor pond for broodstock grow-out. The capacity here is 240 million post larvae/year.

"The potential for more post larvae production encourages us to expand our premises. In 2016, when we started, we had only 42 larval and 4 nursery tanks in the small footprint of 4,000m^2 in Lenggeng, Negeri Sembilan. Teamwise, we expanded from a staff of only 4 in 2020 to 20 in 2021 and today, at 27."

GKA sells post larvae at MYR0.10-0.12 each (USD25,000-USD30,000/million PL), comparatively higher that other hatcheries using wild broodstock (MYR0.07/PL or USD17,500/million PL).

Internationally, there is demand for its post larvae, such as from India, where interest to return to farming the freshwater prawn (marketed as scampi) is picking up fast. India's market is estimated at 5 billion post larvae. There are also enquiries in Thailand. In 2021, it had airfreighted a consignment of 150,000 post larvae to Egypt's El Komy group, for polyculture with tilapia in greenhouses. This followed the signing of a cooperation agreement in 2021. This opens an expansion into the African continent with El Komy which wants to target West African countries such as the Ivory Coast and Ghana.

Research and technical teams are mobilised for the days of injecting the androgenic gland analogue into the post larvae.

Farming the freshwater prawn in Malaysia

Many farmers have the facilities to carry out nursery of post larvae over a month and stock size 2-3g juveniles in grow-out ponds but few focus on using quality feeds to secure high survival rates. Generally, in the subsequent grow-out, survival rates are 50%. Some enterprising farmers achieve 60-70% survival rates during the nursery phase and 80% survival rates during grow-out. Common harvest volumes are 1.2 to 1.5 tonnes/acre (3-3.75 tonnes/ha). The stocking density ranges from 10-15 PL10/m^2. In 4 months, at the lower density, harvests are size 13-15/kg and at the higher density, size 20/kg.

"During the early days of the pandemic, demand was for the premium larger sizes and therefore, we saw a good demand for post larvae. Our revenue rose considerably in 2021," said Giva.

There are four types of markets: Premium live large 100g prawns for seafood restaurants at ex-farm prices of MYR65/kg (USD16.2/kg); live smaller size prawns with ex-farm prices of MYR55/kg (USD13.7/kg) for smaller establishments and home cooking; chilled prawns; and live prawns for sport fishing ponds. In the latter, over 90 days, there are partial harvests of 30g prawns to supply when required. During the closure of activities in the first year of the pandemic, Giva noticed that demand for sports fishing dropped.

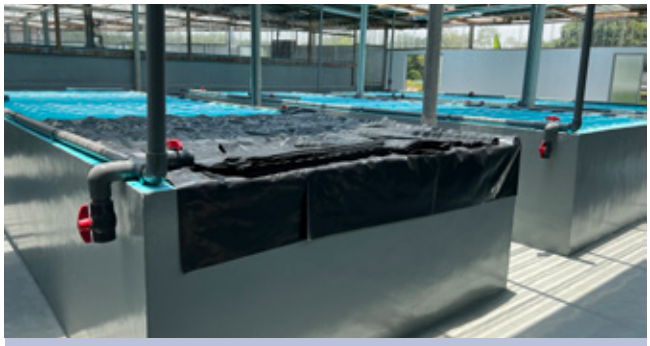
Currently, direct costs of production is MYR25/kg (USD6.25/kg) and when the ex-farm price is MYR55/kg (USD13.7/kg) for live or chilled prawn, the gains are substantial. If demand exceeds supply, as per the situation today, selling prices can be as high as MYR95/kg (USD23.7/kg). In the near future, Giva has projected 3,000 tonnes/year which require 240 million post larvae/year.

New class of hatchery operators

Malaysia has 3-4 large freshwater prawn hatcheries but numerous small backyard and government hatcheries, all dependent on wild broodstock. In its pilot facility, GKA will run a private hatchery with micro-entrepreneurs by providing the training and raw materials. "I want to develop this model to provide hands-on training for international participants. With this move, there is the potential for GKA to collaborate with conventional hatcheries rather than to compete with them," said Giva.

Recently, 500,000 larvae were given to a hatchery for on growing to PL10. In comparison to larvae from wild broodstock, full metamorphosis to post larvae appeared at day 20 and by day 25, 50% PL10 were attained. "I am planning to supply more hatcheries with larvae which they will grow and sell to farms. Ultimately, we gain traction for our broodstock and increase supply of freshwater prawn in domestic markets."

Eliyarajan and Ganeswaran are responsible for water quality, breeding and larval rearing operations at GK Aqua. Their KPI is to strive for 500 larvae/g of broodstock.



New larval rearing tanks to cater for an expansion in production to 20 million PL10/month by 2024.

B2B business in Malaysia

The business model is not just selling post larvae but working with farmers with buy back schemes. It offers post larvae at MYR0.07-0.10 /PL and then buy back a minimum 50% of the harvest at MYR60/kg (USD15/kg) for size 50g/prawn while the market price can be MYR65/kg (USD16.2/kg). The lower offer prices are to take into consideration the lower selling prices for post larvae and technical consultancy services for the farm that it provides. Working with seafood retailers, GKA helps farms in marketing the prawn in its B2C business model. There is quality assurance under the M'Ros branding too.

On their ecommerce platform, the offer is for two sizes of live prawns: XL size of 50-70g/prawn at MYR78/kg (USD19.5/kg) and XXL for size 80-100g/prawn at MYR86/kg (USD21.5/kg). There is good demand for the latter size.

Delivery of post larvae. Giva Kuppusamy with Dr Prakorn who is working with GK Aqua to develop polyculture of freshwater prawn with vannamei shrimp in brackishwater ponds.

The research team is working on alternative feed ingredients for broodstock, hatchery and grow-out feeds such as Sesbania sp plants.

Expanding national production

GKA has partnerships with 30 experienced farmers with or without land. Often the whole family enters freshwater prawn farming such as the case of a successful farmer in Kuala Pilah, Negri Sembilan who can now produce 20 tonnes/year of freshwater prawn. It is also working on several strategies, including working with the Department of Fisheries and Agro Bank Malaysia to expand both post larvae and national production of freshwater prawn. "We want Agro Bank to make GKA as an anchor company. The bank will provide MYR50,000 (USD12,500) soft loans but the money will not be disbursed to the farmer. We have already secured the land. We will dig the ponds, put our main management team to assist the farmer and we will have a buy back scheme. Sales proceeds go into the escrow account. This is a win-win situation as we get farmers to enter prawn farming and we can develop our business both in the supply of post larvae as well as in the marketing of freshwater prawn," explained Giva.

This is to create jobs for new graduates as well as to get them into aquaculture. "We hire, train and retain those interested to be in this program. They complete the program and will be eligible for the soft loan. We give a buy back guarantee." Since a usual concern is loss of interest after some time, Giva said, "We do not leave them alone after the training period. We have the management team to guide them along. We call them MUGA or Malaysian udang galah entrepreneurs. We include digitalisation and block chain technology, handled by an India based company called SourceTrace. Later, we hope to collaborate with a FinTech company."

In his projected cash flow, Giva said that construction of each 1,000m^2 pond will be MYR5,000/pond (USD1,250/pond) and with three ponds, these new entrepreneurs may earn almost MYR6,000/month (USD1,500/month), which is double the basic salary of a new graduate. The rate of return is 12%.

There is also a potential to introduce freshwater prawn farming in rice fields with 10% conversion of each hectare of rice field which Giva called the UGADI program. However, as rice production plays a food security role, we need to focus on selected areas. The advantage with this prawn, is that we do not need deep ponds, therefore we can build dykes upwards."

Broodstock in spawning tanks. The ratio is 500 neofemales to 100 male broodstock from the local population.

At present, GKA's current production is 3 million PL10/month while the target is set at 5 million PL10/month. The projection is 20 million PL10/month by 2024. On whether the availability of more post larvae and consequently larger volumes of production will affect selling prices of marketable prawns, Giva said, "What we also want is for Malaysians to enjoy quality freshwater prawn, not those of poor quality due to short supply in markets. With growth of the middleclass and increasing affordability, I have a very positive outlook on prices."

Meanwhile Giva is upbeat on investment funds totaling MYR4 million (USD<1 million) from local venture funds to run these programs. GKA's focus is also on how to create more sustainable and cost-effective grow-out feeds using local plant meal alternatives such as from the *Sesbania* sp. and utilising maggots either directly or in formulated feed for the freshwater prawn.

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The effects of *Lactobacillus* as probiotics on mud crab larval culture performance

Lactobacillus casei treatments at two concentrations gave significantly higher survival rates during the early to mid-day post hatchings.

By Kok Onn Kwong, Anita Talib, Md. Arif Chowdury, Wan Mustapha Wan Din, Khairun Yahya and Alyaa Abdulhussein Alsaedi

Right: Female mud crab Scylla paramamosain with berried eggs adhering to the pleopods of broodstock's abdomen, the dark colour signals that hatching will take place soon. Left: Scylla paramamosain larvae at the DPH0.

One major obstacle to the growth of *Scylla* or mud crab aquaculture is the low supply of hatchery produced seed due to bacterial diseases and high mortality rates. Antibiotics are used extensively in *Scylla* larval culture to improve survival, but its use poses numerous risks.

Probiotics can control the microflora and pathogenic bacteria, degrade unwanted substances, enhance the quality of the environment through lowering toxic gasses, increase the number of food organisms in the culture water, improve the host nutrition, and enhance their immunity to diseases (Kesarcodi-Watson et al., 2008). Improved water quality was shown with the addition of some probiotics (Verschuere et al., 2000). However, different probiotic species and strains provide differing benefits (Senok et al., 2005). The aim of this study was to determine the larval culture performance of *Scylla paramamosain* larvae with various concentrations of a single strain, respectively of two probiotics, *Lactobacillus casei* and *Lactobacillus plantarum*.

Larval culture and probiotic trials

Commercial yogurt products are potential sources of the *Lactobacillus* probiotic. The commercial yogurt product Yakult® with live *L. casei* (Shirota strain) at a concentration of 3.75×10^8 CFU/mL was chosen as test probiotics. It is a promising candidate for *L. casei* due to its high quality, ready availability, low cost, and free of preservatives, colourings and stabilizers.

Pure *L. plantarum* in Man-Rogosa-Sharpe (MRS) broth was obtained from The School of Pharmaceutical Sciences, Universiti Sains Malaysia (USM). The culture method for *L. plantarum* was done according to Talpur et al. (2012), with some modifications. The plating was on MRS agar with 5% w/v NaCl and stocked onto MRS slants. Culture conditions were at 37°C in MRS broth for 24h. Following this *L. plantarum* cells were centrifuged at 12,000×g for 15 mins, rinsed and then resuspended with sterilised seawater and kept at 4°C. Fresh cells were quantified with optical density using a spectrophotometer. Serial dilutions ranged from 1:10 to 10:10 with triplicate plate counts.

Supplementation of the larval culture water with *Lactobacillus* was done in two trials. In Trial 1, the commercial yogurt product was used as is. In Trial 2, only the *L. plantarum* cells without the culture medium were used, where the latter was discarded by centrifugation, discharging the supernatant, and resuspending the *L. plantarum* cells in sterile seawater.

Trial 1 tested the two concentrations of *L. casei* as probiotics in *S. paramamosain* larval cultures. The control had no probiotics added. The main objective of this trial was to determine the effects of *L. casei* on survival rates, *Vibrio* colony counts and water quality in mud crab larval cultures. The two treatments for *L. casei* were at concentrations of 1.88×10^8 CFU/mL (T1) and 3.75×10^8 CFU/mL (T2). These concentrations were chosen as previous studies using *L. casei* as a probiotic on aquaculture organisms had used a similar/equivalent density. In Trial 1, 9,000 larvae were divided into nine tanks, with three control and six treatment tanks.

Trial 2 tested *L. plantarum* cells at two concentrations, 1.00×10^2 CFU/mL (T3) and 5.00×10^2 CFU/mL (T4) and their effects on larval survival, *Vibrio* colony counts and water quality in mud crab larvae culture. The probiotic concentrations were chosen as they represented similar and equivalent concentrations which gave the best overall culture performance of larval Portunidae crabs, when *L. plantarum* was used as the probiotics in previous studies.

Bacterial colony counts, microbial identification and water quality

For the enumeration of Vibrio, the surface plating technique was used (Ohashi et al., 1978). A summary report from DXN Holdings Bhd. for identification of the yellow and green *Vibrio* colonies in this study was as follows. The colonies were re-isolated, and incubated. Single colonies were then isolated, Gram stained, followed by testing with suitable identification kits. The sample was isolated on TSA to get the fresh culture and then incubated for 72h at 37°C, followed by Gram staining of the single colony to differentiate the group of unknown bacteria. A suitable identification kit was then selected to confirm the species of bacteria.

Water quality for the larval culture was monitored every two days from a randomly selected tank within each treatment. Parameters measured for all experiments and trials were dissolved oxygen (DO) temperature, salinity, pH, ammonia, nitrite and light intensity.

Larval survival rates

The larvae used in this trial were of good quality, as evidenced by the active swimming and phototactic nature for day zero post hatch (DPH0) . Survival rates of larvae for treatment groups at various DPH are shown in Table 1. In Trial 1, we showed that compared to the control, there was a significantly higher survival in treatments T1 and T2 at DPH4 and with treatment T2 at DPH6. At DPH8, all treatment groups showed higher survival and at DPH10, survival was higher in the T1 treatment compared to the control. No significant difference in survival rates were seen between the treatments at DPH8 and DPH10.

In Trial 2, larvae survival rates for the different treatments at various DPH (Table 1) showed that compared to the control, there was a a significantly higher survival in the *L. plantarum* treatments at DPH4 and higher survival rates in the T3 and T4 treatments at DPH2. In all the other cultures and DPHs, there were no significant differences between the treatments.

Microbial colony counts

Lactobacillus casei deep colonies on MRS agar were light brown/white to slightly yellow in colour, smooth, circular with whole margins, lens and diamond-shaped, following incubation at 37°C for 48h. Growth took place in MRS broth with noticeable turbidity. When viewed under a light microscope, *L. casei* cells were rod-shaped, 1-2 × 0.4-0.8µm in size, occurred singly, in pairs, and in chains of three to four cells. Flagella were not present, and the bacteria were not motile. Yellow and green *Vibrio* colonies plated on TCBS were identified as *Vibrio cincinnatiensis* and *Vibrio parahaemolyticus*, respectively by the commercial laboratory.

Figures 1A and 1B show the *Vibrio* counts for trial 1 where *V. cincinnatiensis* counts were higher for T1 and T2 compared to the control at DPH1 and were higher for all treatments at DPH10. *V. parahaemolyticus* counts for the *L. casei* treatments were 0 CFU/mL at DPH10. There was no significant difference in *Vibrio* counts between any of the treatments at both DPH1 and DPH11.

In Trial 1, water quality for each treatment throughout the larval culture is given in Table 2. The maximum total ammonia level for the T1 and T2 treatments was 1mg/L, compared to the control of 0.5mg/L. Temperature ranges for this trial was 26.7–29.9˚C, salinity 29.3–34.3 ppt., DO 5.6–7.58, pH 8.0–8.8, total ammonia 0.25–1mg/L, and nitrite 0–1mg/L.

DPH	Survival (%)		
	Control	Treatments	
Trial 1		T1 (1.88×10^8 CFU/mL) *Lactobacillus casei*	T2 (3.75×10^8 CFU/mL) *Lactobacillus casei*
4	5.7 ± 5.7^{a}	99.3 ± 29.2^{b}	70.7 ± 13.3^{ab}
6	2.3 ± 1.2^{a}	19.0 ± 1.5^{ab}	49.7 ± 11.9^{b}
8	2.0 ± 0.6	3.0 ± 1.0	9.3 ± 4.4
Trial 2	Control	T3 (1.00×10^2 CFU/mL) *Lactobacillus plantarum*	T4 (5.00×10^2 CFU/mL) *Lactobacillus plantarum*
2	54.7 ± 13.7	83.3 ± 10.1	72.7 ± 12.7
4	47.7 ± 2.2^{a}	74.3 ± 7.3^{b}	90.7 ± 6.6^{b}
Between treatments, values with different superscripts within each DPH were significantly different from each other ($P<0.05$).			

Table 1. Survival rate (%; mean ± standard error) of *Scylla paramamosain* larvae in Trial 1 with control, *Lactobacillus casei* (Shirota) at two concentrations (T1 and T2) in the culture water, at various days post hatching (DPH) and in Trial 2, control and *Lactobacillus plantarum* at two concentrations (T3 and T4) in culture water at various DPH in Trial 2.

The water quality ranges during the larval culture period of Trial 2 are shown in Table 2. Water quality parameters were measured in ranges as this was the most common form of presentation in the aquaculture literature, including those used for *Scylla*. The highest total ammonia levels reached during the culture period was 4mg/L, with treatment T4 and the control having the highest average levels. The maximum nitrite and nitrate levels for all treatments were 5 and 10mg/L, respectively. The pH range for all treatments was 7.8-8, total ammonia was 0.25-4mg/L, nitrite was 0.00-5mg/L, nitrate was 0-10mg/L, and light intensity for this trial ranged from 1249-6970 lux.

Improvement in survival rates

Trial 1 showed that the addition of *L. casei* as water probiotic improved the survival rate of the mud crab larvae. There were higher survival rates during the early culture periods of the *L. casei* treatments compared to the control. Likewise, the significantly higher survival in the *L. casei* T4 treatment compared to the control at DPH6, and the higher survival in all the *L. casei* treatments compared to the control at DPH8 shows potential for using this probiotic in mud crab larval cultures. There were also higher survival rates in *L. casei* at T1 compared to the control at DPH10. This trial has shown that using *L. casei* resulted in higher survivals in *S. paramamosain* larval culture between DPH6–10, and these results are supported by studies in the literature using similar *Lactobacillus* on crustaceans, such as *Portunus pelagicus*. This suggests that *L. casei* from Yakult® is an excellent and economical probiotic option for *Scylla* larviculture.

Trial 2 showed that the application of *L. plantarum* through culture water had beneficial effects on the survival rate of larvae during the early culture period, for the results have shown larval survival rates of 74.3-90.7 ± 7.3% in treatments with this probiotics compared to only 47.7% in the control at DPH4. This finding shows potential and similar trends with what other researchers have shown using *Lactobacillus* as probiotics in crustacean cultures, including Portunid crabs.

Vibrio counts

In Trial 1, *Vibrio cincinnatiensis* counts were higher for the control and in both *L. casei* treatments during the later culture period. Lower counts of *V. parahaemolyticus* during the latter part of the trial indicate that *L. casei* inhibited the growth of this pathogenic bacteria. This result could be due to the ability of *L. casei* to produce bacteriocins inhibiting growth of other bacteria. More studies with this probiotics on *Scylla* larval cultures are suggested to confirm this finding.

In Trial 2, the overall higher *V. cincinnatiensis* counts in the *L. plantarum* treatments compared to the control, is in accordance with Moriarty (1999). In contrast to green *Vibrio* colony counts in cultures whereby the addition of certain probiotics have been effective in reducing its numbers, non-pathogenic yellow *Vibrio* colony counts has been known to increase with the addition of probiotics. *L. plantarum* reflected positive effects on culture in this trial and can be used as a tool for the *Scylla* larviculture. Further studies are also suggested.

Parameters	Control	Treatments	
		T1 (1.88 × 10^8 CFU/mL) *Lactobacillus casei*	T2 (3.75 × 10^8 CFU/mL) *Lactobacillus casei*
Temperature (°C)	27.10 – 29.60	26.80 – 29.90	26.70 – 29.70
Salinity (ppt.)	29.30 – 34.30	29.30 – 30.30	29.40 – 30.70
Dissolved oxygen (mg/L)	5.84 – 7.58	5.60 – 7.14	5.85 – 6.68
pH	8.00 – 8.80	8.00 – 8.20	8.00 – 8.20
Total ammonia (NH_3-/NH_4+; mg/L)	0.25 – 0.50	0.50 – 1.00	0.25 – 1.00
Nitrite (NO_2-; mg/L)	0.00 – 0.25	0.00 – 1.00	0.00 – 1.00
pH	7.80 – 8.00	7.80 - 8.00	7.80 – 8.00
Total ammonia (NH_3-/NH_4+; mg/L)	0.25 – 4.00	0.50 – 2.00	0.50 – 4.00
Nitrite (NO_2-; mg/L)	0.00 – 5.00	0.00 – 5.00	0.00 – 5.00
Nitrate (NO_3-; mg/L)	0.00 – 10.00	0.00 – 10.00	0.00 – 10.00
Light intensity (lux)	2020 – 6970	1249 – 2470	1815 – 2090

Table 2. Water quality ranges in the larval culture tanks for the control and treatments in Trial 1 and Trial 2.

Effects on water quality

In Trial 1, water quality was within the tolerable ranges for *Scylla* larvae growth. The addition of *Lactobacillus* in aquaculture is known to lower pH of culture water. There was no noticeable difference in pH of the *L. casei* treatments compared to the control. We postulate that this could be due to the relatively low concentration of *Lactobacillus* added.

In Trial 2, the maximum ammonia level of 4mg/L for the control and *L. plantarum* in treatment T4 was at the high end of *Scylla* tolerance. Likewise, the maximum nitrite levels of 5mg/L in this trial are high for *Scylla larvae*. According to Ma et al. (2009), *Lactobacillus* can improve water quality by facilitating the removal of ammonia from culture water. However, no such effect was observed in this trial, and again, this could be related to the low dosage used.

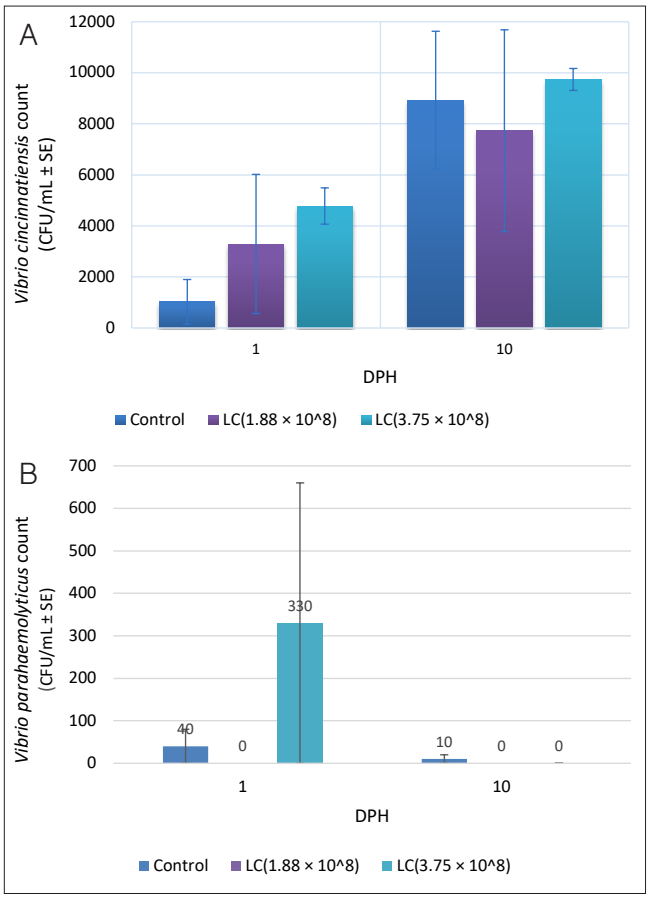

Figure 1. (A) *Vibrio cincinnatiensis* and (B) *Vibrio parahaemolyticus* counts (CFU/mL; mean ± standard error) in the *Scylla paramamosain* larval culture water in the control and *Lactobacillus casei* (Shirota) treatments T1 (LC 1.88x10^8 CFU/mL) and T2 (LC 3.75 x10^8 CFU/mL) at days post hatching (DPH) 1 and 10 of Trial 1.

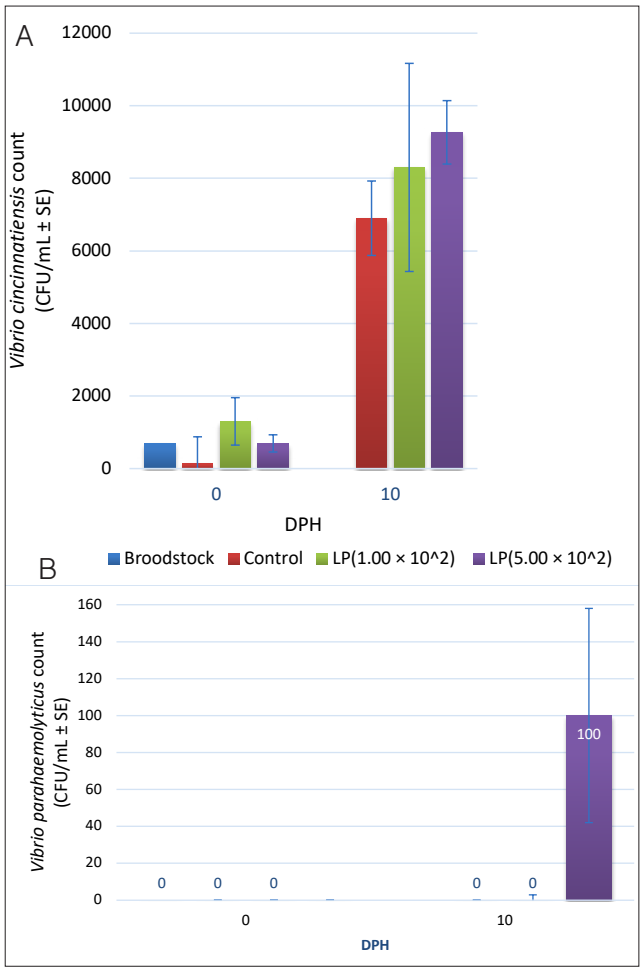

Figure 2. (A) Yellow and (B) green *Vibrio* counts (CFU/mL; mean ± SE) for culture water of *Scylla paramamosain* larvae in the control and *Lactobacillus plantarum* treatments T3 (LP 1.0x10^2 CFU/mL) and T4 (LP 5.00 × 10^2 CFU/mL) at various days post hatching (DPH) of Trial 2.

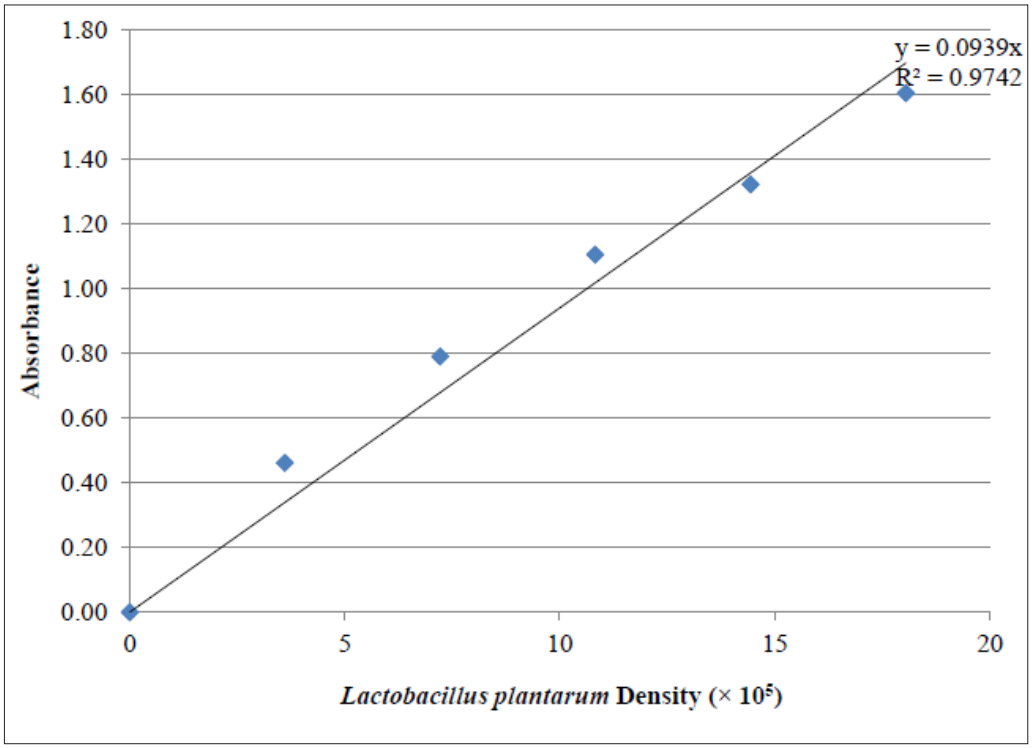

Figure 3. Graph showing the standard curve of *Lactobacillus plantarum*, r^2 = 0.9742, n = 6 (Trial 2).

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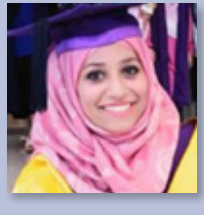
Kok Onn Kwong, PhD is currently with the Borneo Marine Research Institute (UMS), Sabah, Malaysia. Email: kokonn.kwong@gmail.com

Anita Talib is with the Center for Marine and Coastal Studies (CEMACS) and School of Distance Education, Universiti Sains Malaysia (USM), Penang, Malaysia.

Md. Arif Chowdury and **Wan Mustapha Wan Din** are at CEMACS, USM, Penang, Malaysia.

Khairun Yahya is at CEMACS and School of Biological Science, USM, Penang, Malaysia.



Alyaa Abdulhussein Alsaedi is at the School of Industry Science, USM, Penang, Malaysia.

Precision farming in aquaculture with accessible microbiome management

Aquaculture has an enormous potential to ensure food security in a sustainable way. Animal health and water quality are therefore crucial aspects. Frequent and unpredictable disease outbreaks are detrimental to farm yields. By better controlling the microbiome based on robust and detailed data, the industry can take the necessary next step towards sustainable and reproducible farming.

KYTOS *and* **I&V Bio** are now joining forces to bring rapid sample logistics (I&V Bio) and local microbiome analysis (Kytos) to the six most important shrimp producing countries (Thailand, Indonesia, India, Vietnam, Ecuador and Bangladesh). The partnership will install local and independent Kytos labs to serve aquaculture farms and hatcheries with cutting-edge high throughput microbiome management tools.

The partnership combines I&V Bio's long-standing expertise in serving aquaculture clients every single day of the year with Kytos' novel microbial fingerprinting technology that brings a holistic view on the aquaculture microbiome health. Vietnam has been selected as the first country where a central sample collection point, equipped with Kytos' automated microbiome analysis platform will be established. The other countries will follow swiftly.

Today, Kytos technology can already characterise most of the microbial life (fungi, bacteria and algae) in the water, sediment and shrimp of a pond. Functional indicators, devised using machine learning, connect these data to farm actions such as biofloc formation, water maturation, and microalgae blooms. This ever-expanding list of indicators will help aquaculture farmers to shift the focus from mitigating diseases to an altogether improved management of the microbiome in their systems.

Frank Indigne (CEO, I&V Bio, left) and Ruben Props (CEO, KYTOS)

Precision farming in aquaculture

In the fields of water and animal treatments, Kytos can now open the microbial black box in aquaculture systems by using so-called "microbial fingerprints". This assessment provides farmers with microbial health insights that empowers them to take targeted actions to optimize animal health and production yields.

Frank Indigne, CEO of I&V Bio, said, "The need for improved health management and disease prevention is as critical today as ever. Effective biosecurity will always be key to boost the commercial viability and environmental responsibility of the shrimp farming industry."

Kytos uses big data and artificial intelligence to reduce aquaculture's unpredictability by creating practical tools that help all stakeholders make informed management decisions to improve their farm performance. Ruben Props, co-founder and CEO, said, "Shrimp aquaculture has largely been deprived of the benefits of new microbiome technologies and knowledge. We are on a mission to change that *status quo*. This partnership is an important step to bring our microbial fingerprinting platform to the farmers across the world. By working closely with all stakeholders in the industry we will create a unique opportunity to manage the microbiome together, for the benefit of the industry."

I&V Bio specialises in the daily and fresh delivery of its live feeds and solutions to the aquaculture industry. It was founded 8 years ago, by Frank Indigne and Luk Van Nieuwenhove when they started working on a revolutionary solution that has taken the Artemia-hatching burden away from shrimp hatcheries by creating Artemia hatching facilities. These facilities combine know-how, experience and new technologies to produce Artemia nauplii in a professional and industrial way. Currently, the I&V Bio Group has established Nauplii Centres in 6 countries (see box). www.iandv-bio.com

KYTOS is a microbiome technology company developing microbiome management solutions at the frontier of technological innovation. It has its origins in the Centre for Microbial Ecology and Technology (CMET) at Ghent University, where it builds on decades of world-leading expertise in the management of microbial communities. Its transform partners into expert microbiome health stewards by empowering them with a unique blend of data science, technology, and microbial ecology insight. www.kytos.be

New Artemia Nauplii Center in Cox's Bazar, Bangladesh

In January, I&V Bio announced that a new Artemia Nauplii Centre located in Cox's Bazar, a centre of shrimp farming in Bangladesh will begin to supply live Artemia on a daily basis to hatcheries.

Today, it has eight Artemia nauplii centres worldwide and is planning for two more locations. In Asia, there are three centres (2 in Kakinanda and one in Gudur in Andhra Pradesh) in India and one each in Lampung, Indonesia (which started in 2018), Ninh Thuan, Vietnam and Bangladesh. It opened a centre in Ecuador in January 2020.

These centres deliver daily, live and ready to use Artemia instar1 (INSTART 1) nauplii and enriched Artemia nauplii (INSTART Energy) to hatcheries. Nauplii are packed in 800g trays, equivalent to one can of Artemia at 70% hatching rate. Products are of consistent quality which enables the hatcheries to follow strict biosecurity protocols and relieving them of the burden of hatching Artemia cysts in often sub-optimal conditions.

SHRIMP 2022

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Launch in India of new improved post larvae feed

From left to right, R. Balaraman, Mark Rowel Napulan, Muthukaruppan (Vice President, AISHA), Padmanabha Reddy, Panchu (Uni Bio SPF Monodon hatchery), Ravikumar (Golden Marine Harvest Group of Hatcheries) and Kalraj (President AISHA , Tamil Nadu Chapter & MD Royal Shrimp Hatchery).

In March, **Zeigler Bros.**, Inc. in cooperation with **Priyanka Enterprises** successfully launched EZ Artemia Ultra in Tamil Nadu. The launch of the third generation of EZ Artemia was attended by over 50 participants representing 32 big hatcheries from the Chennai coastal region.

Padmanabha Reddy, Priyanka Enterprises during the open forum. Seated is R. Balaraman, General Manager of Priyanka Enterprises.

Originally developed as a synthetic substitute for Artemia, this complete and balanced diet has become a global standard for the industry. EZ Artemia Ultra formulation exceeds the attractability, digestibility and nutritional value of Artemia nauplii. Over the years, the best ingredients have been incorporated into highly digestible microparticle matrix, precisely manufactured and sized for maximum consumption. The microencapsulation process protects sensitive pigments, fatty acids, enzymes, vitamins and other nutrients in a soft moist easy to consume matrix. Shelf stable, convenient, biosecure and cost effective, sales of EZ Artemia have grown over the years with many hatcheries significantly reducing their use of Artemia nauplii and some eliminating Artemia nauplii completely.

Over the past few years, R&D at Zeigler has improved the formulation to incorporate new powerful ingredients while removing terrestrial proteins. A second area of advancement was on the manufacturing process, enabling the incorporation of more nutrients into each microcapsule, improving digestibility, making the capsules more buoyant while maintaining water stability. The third area of focus was in demonstrating performance improvement. Product development efforts focused on feeding of EZ Artemia as the only diet for PL2-PL12, assuring maximum performance and improved larval fitness and gut health as demonstrated by higher survival and growth.

The event was hosted by Balaraman Radakrishnan, newly appointed General Manager of Priyanka Enterprises who is also a seasoned technical and sales professional with more than 30 years of experience in the field of shrimp aquaculture for both hatchery and farm. Mark Rowel Napulan, Sales Manager for Asia, Zeigler Bros., Inc. led the event with his presentation

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entitled “EZ Artemia Ultra, the best just got better”. Napulan emphasised the importance of increased biosecurity and understanding potential pathogen carriers to produce clean post larvae. He believes that there is a need to balance the risk between using live and fresh feeds versus post larvae productivity. “After 3 years of continuous R&D work at our Z-ARC (Zeigler Aquaculture Research Center) in Florida, I am very excited to present to you the key features of this improved product. This diet now comes with improved buoyancy allowing the particles to remain suspended in the water column indefinitely with good aeration, maximising productivity from flat as well as parabolic larval systems. We have incorporated our special blends of Rescue probiotics into the micro-capsules to promote gut health and help protect shrimp against pathogenic vibrio. In the liquid fraction, we have incorporated our Remediate water quality probiotic blend designed for waste digestion and toxic gas control for a healthier tank environment. The formulation includes V-Pak, Zeigler’s immune enhancement feed additive for stress and disease tolerance.

Mark Rowel Napulan, Sales Manager for Asia, Zeigler Bros., Inc.

“EZ Artemia Ultra users can adapt different feeding strategies depending on their experience in using liquids. Some hatchery managers have found that continued feeding of this diet after discontinuation of feeding of Artemia nauplii helped reduce cannibalism and resulted in significantly higher survival”.

As a partial Artemia replacement, laboratory and field studies have demonstrated improved lipid deposition, growth and survival compared to control tanks fed with 100% Artemia nauplii. In addition, production costs were reduced, and profits increased.

EZ Artemia Ultra has been demonstrated to successfully replace 100% of the Artemia in the diet, eliminating the need for the additional capital expense associated with Artemia hatching systems. Complete replacement of artemia significantly reduces the risk of *Vibrio* and microsporidian contamination, while improving gut health of larvae. www.zeiglerfeed.com

2nd Announcement

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The Shrimp Book II

This new volume of **The Shrimp Book** is complementary to the first, bringing together new knowledge, new technologies, perspectives and ideas from 98 international authors, from both academia and industry.

The book is edited by **Victoria Alday-Sanz**, editor of the first The Shrimp Book who said, "Twelve years have passed since the publication of the first volume. While the content of The Shrimp Book remains valid and useful, I felt a new volume was needed that would capture the developments that have taken place over these years."

Alday-Sanz has over 35 years' experience working on diverse aspects of shrimp and fish biosecurity covering understanding of disease process, diagnostics, sanitary legislation, health management, genetics and biosecurity. She has often collaborated as an expert for international organisations such as FAO, EU, EFSA and OIE. "I have spent these twelve years as a "shrimp farmer" at industrial scale and while the first volume was from the perspective of my academic years of experience looking into shrimp farming, this new volume is conceived from my farming experience and still looking for the integration of academia and industry. You will be able to see these different perspectives particularly in the selection and combination of authors and chapters of The Shrimp Book II."

Alday-Sanz described the book which has six parts with 27 chapters. Part I on sustainability and insurance, is followed by Part II on the shrimp as an animal: functional anatomy, its genome and genetics. Part III covers production systems: microbial, water and oxygen management, and Part IV feeds and feeding (subedited by DA Davis) including feeding behaviour and automatic feeders. The fifth part is on biosecurity covering shrimp response to virus, epigenetic management, new and old pathogens, and disinfectants. Finally, there is Part VI on post-harvest issues (subedited by I Karunasagar) looking into trade and quality control concerns.

Alday added, "As a deliberate editorial policy, there has been no attempt to have a uniform structure, the approach or the style of the chapters. The personal backgrounds and experience of the authors is reflected in their text which we hope will bring some closeness to the reader. This level of "freedom" had to be extended to the nomenclature of the white shrimp as some of the authors had strong views on whether *Penaeus* or *Litopenaeus* genus should be used, so the reader will find both nomenclatures used in the chapters."

The Shrimp Book II is addressed to a diverse readership; for shrimp producers and service providers, researchers and students in any field of shrimp culture and to those involved in the regulation of the industry. It has been a massive effort bringing together academic perspectives and the most recent development in field practices.

Alday-Sanz had this message for shrimp producers who have patiently taught her over the years and have shared both their deep insights as well as their intuitive knowledge. "My admiration for them has continued to bloom. In these last 12 years, adoption of technology has brought great improvements in production and we have seen the shift in trends, particularly in the West. We are now at the edge of a new era of developments thanks to the molecular tools which will provide a completely different level of understanding of the production ecosystems, the shrimp physiology and the pathogens that will open up new approaches, will question the *status quo* and will pose even more questions."

Publisher: 5M, UK. https://5mbooks.com/product/the-shrimp-book-ii

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Organisers have unveiled the first look for the 13th AFAF virtual venue on the website. https://13afaf.tw/index.php?inter=program&pId=10

This gives the general information on the Gather.town and Webex; platforms being used for the event. Participants are requested to browse through the general information for better understanding of using these platforms.

The 13th Asian Fisheries and Aquaculture Forum (13th AFAF) to be held from May 31 to June 2, is a scientific forum organised by the Asian Fisheries Society (AFS) once every three years to understand the global trends and addressing issues faced by the fishery and aquaculture industry.

Program

A detailed program for the 3-day forum has been uploaded on the website. The program features 6 Scientific sessions and 8 interesting topics with on-demand oral presentations and poster presentations. The conference will start with welcoming remarks from industry leaders led by Prof. Alice Joan G. Ferrer, President, 13th Council, Asian Fisheries Society and Prof. I Chiu Liao Academician, Academia Sinica, National Taiwan Ocean University, Taiwan.

The opening Keynote Address will be on Aquaculture and the Challenges of Sustainability by Prof Chu-Fang Lo, Lifetime National Endowed Chair, National Cheng Kung University, Taiwan.

Prof Fuhua Li, Institute of Oceanology, Chinese Academy of Sciences, China will present "Development of modern breeding techniques and their applications in shrimp breeding."

Plenary and invited presentations at the daily plenary sessions include;

- Intensive monoculture of shrimp at turning point: new biotechnology insights by Emeritus Professor Patrick Sorgeloos, Ghent University, Belgium
- Fisheries and aquaculture in South Asia: Challenges and strategies for ensuring food security by Dr Grinson George, SAARC Agriculture Centre (SAC), Dhaka, Bangladesh
- Development of prevention methods against infectious diseases in shrimp aquaculture by Prof Ikuo Hirono, Tokyo University of Marine Science and Technology, Japan

More information: Registration is still open at https://13afaf.tw/index.php

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This is the new annual top-executive meeting and conference. A first dedicated annual conference and business meeting, aiming to drive the warm water shrimp industry towards a resilient and sustainable future. The Global Shrimp Forum would be an ideal platform for industry participants with diverse experiences and perspectives to share their learning and build better solutions for the global shrimp industry. It will have 400 leading players across the entire supply chain and will cover relevant and urgent business topics such as: Production and market outlooks; Innovation and technologies that transform shrimp production, supply chains and markets; Legal and regulatory challenges; New and upcoming producers and niche products and Finance and investment.

Willem van der Pijl, owner of Shrimp Insights and founder, board member and Managing Director of Global Shrimp Forum, said: "The shrimp industry is fragmented. It consists of hundreds of thousands of farmers, thousands of importers and exporters, and many more companies that support the industry with ingredients, technologies, services and finance and investment. This high level of fragmentation makes it difficult to convene a meeting where all these players feel represented, which is why the Global Shrimp Forum is such an important initiative. Establishing a dedicated platform for everyone who wants to be part of a dialogue on not only the challenges confronting the shrimp industry but also the potential solutions is greatly needed. I view it as my personal mission to make this initiative successful."

The Global Shrimp Forum is initiated by an independent non-for-profit foundation set up by the Aquaculture Stewardship Council (ASC), Shrimp Insights and Contango. The purpose of the Global Shrimp Forum Foundation (GSFF) is to establish a global platform for knowledge sharing, innovation, and industry value-chain collaboration for driving a sustainable future for the industry.

The Forum will meet on an annual basis over a 3-day period in early September in Utrecht, The Netherlands. www.shrimp-forum.com

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INFOFISH announced that the Fisheries Development Authority of Malaysia (LKIM) is hosting the venue for SHRIMP 2022 at The Everly Putrajaya Hotel on 8-10 June 2022. Hence, SHRIMP 2022 will take place as a **hybrid** event.

The sixth edition of INFOFISH World Shrimp Trade Conference and Exhibition, is jointly organised by INFOFISH, the Fisheries Development Authority of Malaysia (LKIM), the Department of Fisheries, Thailand, Network of Aquaculture Centres in Asia Pacific (NACA) and China Aquatic Products Processing and Marketing Alliance (CAPPMA).

Malaysian borders are now open for international travellers with quarantine free travel to Malaysia. At SHRIMP 2022, Infofish assures attendees the thrilling experience to meet and greet with each other, network and explore the business opportunities in this billion-dollar shrimp industry. Those who have already registered/entitled for virtual booths will begiven opportunities to participate in the physical exhibition as well. Limited booths are still available. www.shrimp.infofish.org

Organisers have announced that 11th Symposium on Diseases in Asian Aquaculture (DAA11) will be held **virtually** on 23rd – 26th August 2022 after few postponements due to the Covid-19 pandemic and travel restrictions in all countries. They added that under the circumstances, the virtual mode will be convenient and best option for all participants.

The triennial symposium is a hub that covers core aspects of aquatic animal health including current research developments, trends, the future of the aquatic animal health industry and more. DAA11 provides a forum for interaction among professionals, academicians, and experts in the fields of aquatic animal health. It welcomes all researchers, business professionals, industry and academicians to join and share their research findings at DAA11. www.daa11.org

2022

May 24-27
World Aquaculture
Merida, Mexico
www.was.org

May 31-June 2
13 AFAF – Asian Fisheries Aquaculture Forum
Tainan, Taiwan
https://13afaf.tw/index.php

June 8-10
SHRIMP 2022-INFOFISH
Putrajaya, Malaysia
(Hybrid)
www.shrimp.infofish.org

June 14-15
Blue Food Innovation Summit
London, UK (In person/virtual)
www. bluefoodinnovation.com

June 22-23
Tropical AgTech Conference, Hilo
Hawaii, USA
www.tropagtech.com

June 23-25
Aqua India 2022
Chennai, India
(In person)
www.aquaprofessional.org/aquaindia2022.php

June 27- July 1
Short Course on
Extruded Pet Foods and Treats
Texas A&M, USA
https://foodscience.tamu.edu

August 23-26
DAA11
Kuching, Malaysia (Virtual)
www.daa11.org

September 6-8
Global Shrimp Forum
Utrecht, The Netherlands
www.shrimp-forum.com

September 7-9
Nutrition and Health Asia/Victam 2022
Bangkok, Thailand
https://victamasia.com/

September 13-15
SPACE
Rennes, France
www.space.fr

September 27-30
Aquaculture Europe 2022
Rimini, Italy
www.aquaeas.eu

October 5-6
TARS 2022: Aquafeeds
Ho Chi Minh City, Vietnam
www.tarsaquaculture.com

November 9-11
Aquatica Asia
Jakarta- Indonesia
https://aquaticaasia.com/

November 29-December 2
World Aquaculture Singapore 2022
www.was.org

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