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Feed Innovation:

The Multi-Billion Dollar Effort To Drive Aquaculture Growth

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seafood business news from beneath the surface

Report Author

Matthew Craze

JOURNALIST AND RESEARCHER

Matt initiated Bloomberg Businessweek's dedicated commodities news coverage from Europe and Latin America during a 11-year career. He has been writing about seafood markets for Undercurrent News since 2015 and recently completed an MBA at Cornell University.

Edited by:

Tom Seaman

EDITOR AND CO-FOUNDER, UNDERCURRENT NEWS

Tom is the editor of *Undercurrent News*, which he co-founded in 2012. He has been reporting on the seafood industry since 2005, including as assistant editor of Fishing News International, and online editor at Intrafish Media.

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Jovana Markovic, Graphic Designer

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E1 Studios, 7 Whitechapel road,
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Table of Contents

Appendix of contacts

Appendix of charts

FEED INNOVATION

Executive Summary

Aquaculture needs new nutrients to replace dwindling global availability of fishmeal and fish oil, and it needs them fast to continue the industry's exponential growth pattern. This race against time involves a multi-billion-dollar effort from the cross disciplines of agriculture, biotech and genetics.

Peruvian anchovy, the world's largest fishery, continues to disappoint the global marketplace for fishmeal and fish oil. After three consecutive years of El Nino in the Pacific Ocean from 2014-2016, the Peruvian government announced fresh setbacks for the second season of 2017, leading to a price surge in global markets.

The amount of fish oil found in salmon feed can't be lowered anymore without compromising the healthy protein message that the industry thrives on, said Pearse Lyons, the founder and CEO of US animal nutrition giant Alltech.

"This is a bad story waiting to happen," he warned at the Global Outlook for Aquaculture Leadership, or GOAL, conference in Dublin in 2017.

Feed manufacturers have scoured the face of the planet to find new ingredients that can scale and become reliable sources for feed formulas. Biotech allocated significant research and development budgets to the challenge. And the power of "big ag", the term given to multinational agricultural traders, adds to the effort in scaling up new ingredients that can replace nutrients found in anchovy and sardines.

The rewards on offer are huge. The world requires much more protein to adequately feed a global population that will grow to 10 billion people by 2050, according to the United Nations' Food & Agriculture Organization (FAO). Aquaculture offers lower feed conversion ratios than land-based animals such as chicken, cows and hogs, meaning less protein required to feed those extra people.

Atlantic salmon can achieve feed conversion ratios of 1:1, with Cargill recently bettering that with a score of 0.8, according to Joe Stone, the head of Cargill's animal nutrition business. Chickens need to eat 2 kilograms of feed to add 1kg of weight, and cows need 8kg kilos of feed to add 1kg of mass.

The debate needs to move beyond plugging the health benefits of seafood, said Jeff Sedacca, president of Sunnyvale Seafood, the US arm of China's Zhanjiang Guolian Aquatic Products. Aquaculture companies need to prove ethical and sustainability practices through third party certification to earn trust with consumers, he said.

Feed companies have been weaning aquaculture off marine ingredients for years. The massive expansion of soybean farming in the Americas has acted as a counterweight in that process. Salmon

feed went from 59% fishmeal content in 1990 to 10% in 2016, according to Marine Harvest, the company which farms one in every five salmon worldwide. Soy protein concentrate (SPC) is much cheaper than fishmeal priced at $1,800 per-metric-ton. The nutrients supplied by fishmeal counterbalance SPC in feed formulas, both in terms of amino acid profile and digestibility.

"We will always have marine ingredients, but not as a volume ingredient source," said Einar Wathne, the head of EWOS Group, the fish feed division of US agriculture giant Cargill.

The entry into aquaculture of the four agricultural companies collectively known as "ABCD" – Archer Daniels Midland (ADM), Bunge, Cargill and Louis Dreyfus -- is no coincidence. They are experts at delivering food in massive quantities, at scale, and at affordable prices around the globe. The key challenge for any new ingredient is supply consistency, scale, and cost.

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The "soybeanization" of the Americas continues at a strong pace, and takes an increasingly bigger proportion of feed formulas, along with other plant proteins such as corn and wheat. Five consecutive surplus harvests may have swept concerns about food shortages under the carpet, according to the world's leading grains suppliers.

"We've had five successive years of outstanding crops," Stone, from Cargill, said at a Wall Street Journal conference on food matters. "We do run the risk as a society that we are a little too complacent on food safety and security."

Novel proteins are a way of diversifying aquaculture's feed needs away from dwindling pelagic captures and a heavy reliance on agriculture. Innovators are working on a host of ingredients to come up with an entirely new protein source.

"Feed innovation is about finding the required nutrients, and in great volumes. The world does not have endless acres of arable land to make room for new crops," said Mike Verlings, the founder of Dutch seafood investment group Aqua-Spark. New sources of so-called novel proteins are badly needed, he said.

"We don't think what's being done to the Brazilian rainforests is a good thing," Verlings told *Undercurrent News*. "We have to go to a radically new approach where we have new ingredients."

Silicon Valley start-up Calysta demonstrated it can make a single cell protein by powering natural gas through a reactor laden with bacteria, and won financial backing from Cargill. A full-scale production plant is underway in the US in Memphis, Tennessee, and Calysta has announced plans for a second plant in another location.

Start-ups proposing adaptations on Calysta's bacterial fermentation model are also winning attention from investors. NovoNutrients and KnipBio are two US-based companies that propose making single cell protein from carbon-rich waste effluents such as ethanol plants or hydrogen sources. Nutrinsic, a company since acquired by a Chinese firm, made protein from the water reclamation facility of a US-based MillerCoors brewery in Chicago, Illinois. A European Union-funded project is looking to make single cell protein from forestry waste.

Cultivating feed from insects has sparked curiosity in aquaculture. Animals feed off insects in the wild, and their nutrients are suitable for aquaculture feeds, says Aqua-Spark's Velings. Innovators Agriprotein and Protix built strong business models to obtain protein and oils from insects. Despite that progress, no industry player has shown the scale needed to compete with fishmeal prices.

The future of aquaculture unleashed a race between agriculture companies to develop oilseeds with omega-3 rich fatty acids. Nuseed, a Melbourne-based agriculture company, acquired a patented discovery by Australian government scientists to inter-breed omega-3 rich algae with canola and is ramping up a crop breeding program to sell commercial volumes. Cargill will provide close competition for Nuseed, as it works on a similar genetically modified organism (GMO) crop in Montana with German chemicals giant BASF.

Agriculture has the infrastructure to deliver commercial volumes of oil needed to replace limited fish oil supplies, Nufarm and Cargill say. With an increasing likelihood that a crop-sourced omega-3 will be commercial available before 2020, the industry faces an impending debate in introducing a new GMO crop. This becomes relevant as Europe, a major seafood consumer, is GMO-free.

Finding a way to produce more omega-3 will be key in allowing the salmon industry to deliver on its message that salmon protein is healthier than beef, chicken and pork. Salmon contains half the omega-3 levels it did five years ago, according to a 2015 study by Stirling University. Salmon and oily fish are major natural providers of long-chain omega-3 fatty acids needed for heart and brain health in humans. Without these, most of the world is omega-3 deficient.

"They [the salmon farmers] are playing with fire if they decrease the quantity in feed, as it could turn into a 'chicken of the sea'," said Humberto Speziani, the former chairman of Peru-based Tecnologica de Alimentos, known as TASA, the world's largest fishmeal exporter.

Consumers are becoming more familiar with docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), the omega-3 fatty acids with the highest health benefits to humans and animals. The terms appear on food packaging with lists of vitamins and minerals on nutritional labels, and health magazines such as Men's Health extoll their virtues.

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ADM and Bunge are working on omega-3 rich oils derived from algae extracts. Louis Dreyfus CEO Gonzalo Ramirez told *Undercurrent* in 2017 that the firm seeks a partner to expand in the aquaculture market. Royal DSM and Germany's Evonik Industries patented an oil containing both EPA and DHA and plan a full-scale commercial plant in Nebraska.

Nutreco's Skretting spent two decades on its quest to perfect aqua-feed formulas and recently announced a fish-feed grower feed for salmon in conjunction with DSM and Evonik. Despite that progress, affordable forms of new proteins and oil are still years away, said Alex Obach, the head of the company's influential Aquaculture Research Centre research center in Norway.

"For now, algal sources are going to be premium products," Obach said. "The biggest challenge the industry faces is in overcoming regulatory hurdles."

The biotech industry announced huge advancements in food technology in 2017, giving the world a glimpse of a potential paradigm shift in the animal protein market. Tyson Foods boosted its stake in Beyond Meat, a plant-based protein that replicates the experience of eating beef. This technology looks set to encroach upon the seafood industry.

Impossible Foods, a San Francisco-based start-up that makes plant-based hamburger patties that bleed like real meat, told *Undercurrent* that it plans a seafood-like product. New Wave Foods, another Silicon Valley creation, created a synthetic shrimp. Trained master chef James Corwell created a chewy tomato-based sliver that tastes like raw tuna sashimi, with no biochemists involved.

Start-ups are also involved in innovation, both from biotech and beyond, to find novel ways of replacing proteins and oils. Many start-ups pared off against larger companies in the F3 [Fish-Free Feed] Challenge in 2017, which China's Guangdong Evergreen Feed Industry Co won by creating a 100% plant-based feed formula for tilapia.

Although Guangdong Evergreen optimized existing plant-based formulas, the competition attracted a broad range of initiatives involving new ingredients such as rice husks, sugar cane mulch, and poultry by-products.

While scientists look to test tubes and microbial technology for answers, an old-fashioned 20th century industry could provide a nearer term solution. The rendering industry, which deals with the unglamorous task of buying slaughterhouse residue, hopes to get its products into feed compounds.

"My sense is that we will look back at some point in the future and we will say 'why would anyone want to use fishmeal when we have these more effective ingredients now available'," George Chamberlain, the head of the Global Aquaculture Alliance told *Undercurrent.* "We will eventually see that fishmeal will no longer be so essential and we will have much better mixes of ingredients that yield better performance."

Feed providers need to invest more in research and development to meet the goal of replacing feed ingredients, Chamberlain said. Traditional aqua-feed products contain ingredients that act as attractants that are essential in shrimp farming, he said. Cargill recently set up research and development (R&D) facilities in Chile and Thailand to experiment with new feed formulas for salmon and shrimp.

The feed companies say new technology can improve yield and reduce mortality rates by making fish more resistant to illnesses. Mari Moren, a head researcher of the Norwegian seafood research institute, questioned if aquaculture feeds use the best ingredients and said deficiencies in certain nutrients could be behind recent increases in disease rates.

Skretting said Latin America could double its shrimp output by improving feed conversion rates. That's a persuasive argument for farmers. Shrimp feed can account for over half of total costs, according to India's Central Institute of Brackishwater Aquaculture. Chilean salmon farmers pay $1.96 on feed for every kilo farmed, compared with total costs of $5.58/kg, according to Marine Harvest.

Scientists argue that understanding the role microbes play in fish guts provide clues on how to optimize feed formulations. Alltech, Norwegian research institute Nofima, the University of Glasgow and the Scottish Innovation Center combined forces to identify microbial varieties

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in fish, said Phillip Lyons, a research scientist at Alltech unit Coppens International.

Genetics research has a role to play. UK-firm Benchmark Holdings joined forces with the Research Council of Norway to identify fish that require less fish oil in feed formulas. AquaBounty Technologies, the creator of the world's first GMO salmon, says its fish require 25% less feed than regular Atlantic salmon.

Faced with a tough outlook, players in the pelagic fishing industry argue that they have an important part to play in supplying nutrients to global markets. The current ratio of vegetable proteins to marine ingredients in feed makes the industry sustainable, said Elena Conterno, the head of Peru's national fishing society (SNP). IFFO, the marine ingredients organisation, argues that many of the world's pelagic fishing industries run at sustainable levels and are unfairly stigmatized in the feed ingredients debate.

More fishmeal and fish oil ingredients are used in downstream food products. Celebrity chefs are bringing pelagic species back into vogue, especially in the developed world. Jamie Oliver regularly touts grilled mackerel recipes, while Spain's Adrian Ferria and other top chefs backed a 2015 campaign to use more pelagic species in their restaurants.

In Peru, the SNP funded research to reduce the anchovy smell from fishmeal so it can enrich spaghetti or other carbohydrate-rich foods, Conterno said. The omega-3 industry already eliminates odour from fish oil to sell milks and orange juice fortified with omega-3, she said.

Strong voices from both inside and outside of the fishmeal industry argue that marine fish shouldn't go into feed. That is congruent with a growing trend in developed nations to consume less meat. UK-based NGO Forum for the Future created a number of initiatives as part of its 2040 Protein Challenge, from boosting novel protein ingredient companies to getting chefs to find innovative ways of serving dishes with beans and lentils. The forum will ask retailers' help in creating a space for novel feed sources, said sustainability director Simon Billing. This will ultimately help retailers boost the sustainability credentials of their end products, he said.

Enough science exists to replace both fishmeal and fish oil, said John Sweetman of animal nutrition Alltech. The FAO said in its recent report -- the Future of Food and Agriculture: Trends and Challenges -- that a rethink of food systems and government is essential to meet the challenge to supply world markets.

"It's just amazing the amount of innovation going on in aquaculture at the moment," Sweetman said. "All these things are really futuristic and it does require a little time to bring that down from science to industry."

REPORT SCOPE

This report will focus on the discovery of scaling up of new sources of protein and omega-3 feed for aquaculture. Some references will be made to advancements in the rest of the animal nutrition industry. Some of the latter sections of the report enter into broader questions about the future of seafood demand. *Undercurrent* interviewed dozens of researchers, scientists and industry executives for this report. The author visited fishmeal plants in India and Peru, salmon farms in Chile, and trade shows across the world to give a comprehensive view of feed innovation in aquaculture.

We visited Nufarm's R&D facility in Horsham, Australia to observe close hand how the company is scaling up farming of its omega-3 enriched canola plants. We met a group of Australian government scientists in Tasmania who have been leading research into omega-3 fatty acids.

Undercurrent examined the current state of supply and demand in the pelagic fishing industry, quizzing industry executives about long-term trends.

The race to boost Indian shrimp output has required Indian fishmeal importers to source fish from Africa and even consider South America for raw materials supplies.

The first chapter on the pelagic fish industry reviews the state of Peru's anchovy fishing industry, and what past declines in fish stocks from California to Japan can tell us about the future. The impact of global warming on fishing is addressed in this section. We also address what steps the fishing industry needs to take to ensure that it remains relevant in the future, alongside an expected proliferation in alternative proteins and oils.

The second chapter will assess the nutritional components of both fishmeal and fish oil, and what they provide to both animals and humans. This chapter will set the framework for the next two chapters, that will analyse efforts to scale up new sources of feed and omega-3 fatty acids.

The third chapter focuses on innovation to create new sources of protein, coming from both plant-based alternatives to start-ups such as Cargill's joint venture with Calysta. The chapter focuses on the challenge faced by new protein providers, from bacteria to insects. A subsection in this chapter takes a closer look at the futuristic role of grinding up insects into a protein-rich powder for aqua-feed.

The fourth chapter zones in on the omega-3 market, and focuses on agriculture industry initiatives to manipulate algae strains to find new ways of serving these important fatty acids to human beings. We look at the work of agribusiness giants Cargill, Bunge and ADM in trying to claim a stake in this hot new market.

Finally, the fifth chapter touches on the more unknown trends that might provide breakthrough innovations required to overcome aquaculture's biggest obstacle, getting feed. This chapter identifies companies working on ground breaking research, competitions designed to find solutions among the start-up community and also trends such as fake foods, blended foods, and others.
Each chapter can be read independently as a group of separate essays on the main topics, and don't have to be read sequentially.