The fishless wave

Plant-based fish and seafood on the rise

Givaudan

engage your senses

A Givaudan white paper, in collaboration with the University of California, Berkeley

This paper summarises the key findings of a research report prepared by students from UC Berkeley Product Development Programme on behalf of Givaudan.

It explores the current fish and seafood industry, the market for plant-based options, the main challenges, consumer demand and future market development.

With special thanks to UC Berkeley's Product Development Programme (PDP) Director Keith Alexander; PDP Coach, Sudhir Joshi; the field project team which conducted the research: Chieh Mei, Eric Yu, Yuting Zheng and contributor, Amy Huang, Good Food Institute, University Innovation Specialist.

Table of contents

01

A disruptive trend in an uncertain world

The rise of plant-based foods has been unstoppable in recent years. The trend has moved from niche to mainstream and looks set to become an enduring part of the food and drink landscape.

A recent report by BIS research[1] estimates that the plant-based market will reach over $480 billion by 2024, with a projected CAGR of nearly 14% from 2019 to 2024.

Contributing to this growth is the increasing adoption of vegetarian and vegan diets, and the rise of flexitarianism, as consumers balance a 'good for me, good for the planet' approach to food.

And while meat substitutes are the fastest growing sub-category for plant-based products (an increase of 152% in 2019[2]), fish alternatives are expected to see dynamic growth. Investment in plant-based fish and seafood start-ups has already been brisk and new product development is starting to gather pace.

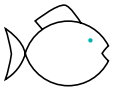
According to a 2019 Mintel report, fish alternatives are predicted to be a top global trend over the next few years, and this rise in interest is reflected in digital and social channels where plant-based fish and seafood are trending.

1) Source: BIS Research – Plant-based Food and Beverage Alternatives: The Revolutionary Trend in the Food-Tech Industry
2) Source: Innova Market Insights

Factors affecting consumer interest

Consumer interest in plant-based fish alternatives is growing and is poised for a rapid rise like other alternative protein products. It is being driven by the same macro trends, but playing out in ways specifically related to the fish and shellfish industry.

Consumer concerns over ethics and the environment

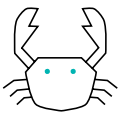


Overfishing
Consumers are increasingly concerned about the impact of overfishing on marine biodiversity and global fish populations. According to the FAO a third of the world's fish stocks (33%) are fished at unsustainable levels.[3]

Climate change
The climate impact of the fishing industry is a growing concern. For example the energy content of the fuel burned by global fisheries is 12.5 times greater than the edible protein energy content of the resulting catch[4]. This is likely to lead to an increased consumer interest in plant-based fish.

Pollution
The plastic debate highlighted the fishing industry's major contribution to marine plastics, mainly through abandoned, lost or discarded fishing gear. Fish farming or aquaculture, is also increasingly seen as a major polluter of water courses through excess feed, fertilisers, pesticides, hormones, effluent and anti-foulants. It is also fresh water, energy and land intensive, putting pressure on local populations.

Consumer health and wellbeing concerns with fish and seafood



Microplastic contamination
Rising levels of microplastic contamination in crustaceans is a growing concern for many consumers. Microplastics damage marine ecosystems and are increasingly found in the gut of fish and seafood. Whilst this is not a major concern for larger species, generally consumed as fillets, it is a growing issue in crustaceans, molluscs and smaller fish species that are eaten whole.

Mercury levels in fish
Fish are the predominant source of human exposure to methylmercury, a potent neurotoxin. In predatory fish species such as tuna and Atlantic cod, mercury levels are increasing – a result of dietary shifts caused by overfishing and increases in sea temperatures.

3) Source: UN Food and Agriculture Organisation
4) Climate and the Oceans, the carbon footprint of fisheries. North Sea Foundation

02

Understanding the fish market

Supply and demand

According to the FAO a third of the world's fish stocks (33%) are fished at unsustainable levels. At the same time, fish consumption is growing worldwide with a 22% global average increase in per capita consumption from 1997 to 2017. As a result, fish prices are rising and this trend is expected to continue as demand outstrips supply for several key species of fish and seafood.

The widening gap between supply and demand is further exacerbated by the impact of climate change. Rising water temperatures, leading to reduced oxygen content, disruptions to ocean circulation, and ocean acidification all threaten the health and distribution of fish stocks.

Aquaculture

Alongside this, fish farming or aquaculture has been growing significantly and now represents around 50% of the world's total fish and seafood production, with continued expansion expected in Africa and Asia.

While it has helped mitigate the reduction in wild catches, its negative environmental impacts are significant and a cause of growing concern. In some instances there may also be consumer perception issues with farm-raised fish due to the occasional practice of using wild fish as feed at the farms. Aquaculture's use of wild fish for feed raises two concerns. First, this practice can exacerbate pressure on marine ecosystems, and second, the use of wild fish for aquaculture feed may reduce the amount of wild fish available for direct human consumption.

Processed fish

The market for processed fish is expected to grow at 4.4 % annual growth with demand in Asia and Europe increasing steadily and a more pronounced growth rate in Africa. As most plant-based fish products are replacements for processed fish, this represents a major market opportunity.

Overfishing	Increasing demand	Rising prices	Aquaculture	Ocean warming
33% of stocks fished at unsustainable levels	22% increase in global per capita consumption	Driven by growing supply gap	50% of world production of fish and seafood	Increased acidity and deoxygenation

03
Challenges for plant-based fish and seafood

Consumers' demand for plant-based fish is rising, but for it to become a regular part of their diet, the look, feel, nutritional content and most importantly taste must all be right.

This presents numerous complex challenges for manufacturers. The process, application and protein base all affect the outcome and it takes skill, experience and the right mix of capabilities and tools to get the desired end result.

This is still a specialist area and working with experienced partners can both simplify the process and speed it up. Building collaboration within the industry with ingredient suppliers and technical experts will help in overcoming challenges and will facilitate development and production.

Which protein source to use?

Choosing the right protein source for any plant-based product is a balancing act for manufacturers.

A number of factors need to be taken into account when selecting a protein including cost, sourcing, nutritional and protein content, functional properties and taste.

Currently, the top choice for manufacturers in the plant-based fish space is soy, due to its high nutritional content, functional flexibility, established supply and consequent low cost, as well as a favourable fibrous structure that performs well in the texturising process. The key drawback is that soy is also an allergen, making it unsuitable for some consumers.

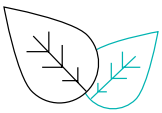
Pea is the next most popular choice. Pea protein contains few or no allergens with an only slightly lower PDCAAS[5] score and protein levels than soy, but it has lower functionality and is high in off-taste. Cost is also slightly higher, with a less well developed supply chain.

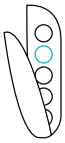
Wheat is also a popular protein source with good sourcing options, low cost, a clean taste, and good functionality but with much lower nutritional content and issues with allergens in the form of gluten.
Other protein choices include chickpea, lentil, flaxseed, faba and navy bean.

Vegetables such as jackfruit, carrot, tomato and aubergine (eggplant) are being used in innovative ways to successfully mimick textural properties in alternatives for sushi and salmon or tuna slices.

Seaweed and algae are another option for manufacturers due to their strong associations with a 'sea' taste. The gel-like texture properties of algae also closely match the texture of shrimp.

For seafood items – mainly shellfish – starch based ingredients are used – with konjiac as the go-to product – which when thickened and mixed with gum closely mimics the texture of real shrimp and can also be applied to lobster, crab, prawn and calamari alternatives. Other starch powders include vegetable root starch and yam flour.





	Soy protein	**Pea protein**	**Wheat protein**
Sourcing	Very well-established	Relatively established	Very well-established
Allergen	Soy	No	Gluten
PDCAAS[5]	0.91 – 1	0.82 – 0.89	0.42
GMO	In some cases	No	No
Off-note	Clean taste with beany notes	High in off taste with beany, pea notes	Clean taste with cereal notes
Functionality	Highly functional	Moderately functional	Highly functional
Price	$	$$	$

5) Protein digestibility-corrected amino acid score (PDCAAS) is a method of evaluating the quality of a protein based on both the amino acid requirements of humans and their ability to digest it.

Texture – a multi-dimensional challenge

Delivering the right eating experience is a vital part of creating a successful product.

Creating fibrosity

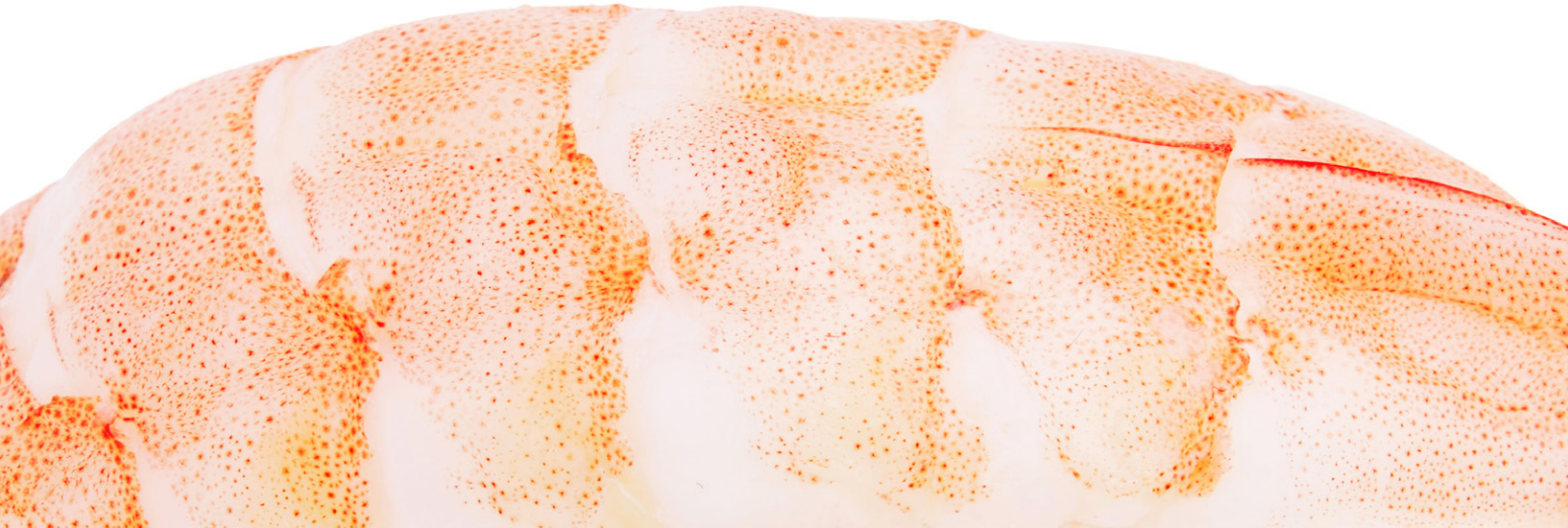
Texture remains the biggest challenge for any plant-based alternative. Currently a texturising process is used to create a dense fibrous structure which delivers the 'meaty' bite and appearance that manufacturers are seeking for fish alternatives.

This is much easier to achieve through a wet texturised vegetable protein (TVP) than dry. While wet TVP is more difficult to shape than dry, flavours can be incorporated into it throughout the whole process, a clear advantage. TVP is well suited to processed fish products such as breaded fillets and fish fingers, but does not recreate the flaky texture of whole fish. This is still the biggest challenge for fish alternatives and has yet to be perfected.

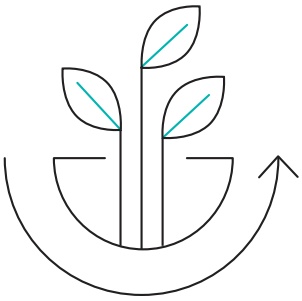
Achieving a desirable texture for ground products, such as crab cakes or fish nuggets is currently less of a challenge. For these popular product types, dry TVP works quite well.

Bite and mouthfeel

Replicating mouthfeel sensations, such as the right resistance in the mouth, a creamy sensation on the tongue or elastic bite when chewing are also important. This can be achieved through a mix of agents – gels, protein isolates, starches – which are incorporated into the recipe along with protein during the production process. The desired mouthfeel will determine which ingredients are needed. Carbohydrate sources such as starches derived from konjac or potato for example, are used to form cross-linked gel structures. This type of technology is frequently employed when the product texture profile is non-fibrous and bouncy, such as shrimp.



Colour –keeping it natural

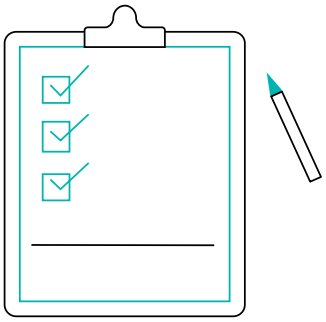


Colour solutions for fish alternatives need to work across a wide range of applications and not only need to look natural but they also need to be natural.

With consumer drivers focusing on health, wellbeing and the environment, natural colours are a must, as are vegetarian and preferably vegan colours and label-friendly ingredients.

The challenge is to accurately mimic a realistic fish colour, which varies in difficulty depending upon the sub-category . For whitefish, it is necessary to whiten the plant protein base, which is usually beige to yellow depending on the formulation. Salmon and crustaceans require orange to pink/red colours with good stability across processes, while for tuna, it is important to realistically replicate the colour change that happens during cooking when fresh, uncooked tuna turns from a deep red colour to brown.

Mind the nutritional gap



Studies have shown that fish and seafood are widely perceived by consumers as having a number of specific health and nutritional benefits linked to high protein, low fat content and high levels of Omega-3 fatty acids.

To widen the appeal of plant-based alternatives outside of the vegetarian and vegan markets, products need to offer similar health and nutritional benefits. As such, product developers should particularly focus on protein and Omega-3 content, especially in non-TVP products such as plant-based shrimp, which often has very low levels of protein.

Flavour and taste

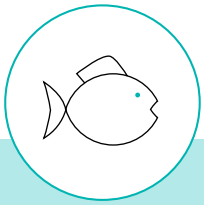
Although texture, colour and nutritional considerations play an important part in consumer decisions, the key factor influencing choice is still the tastiness of the product.

Plant-based fish and seafood product development requires a different way of thinking to fully understand the challenge and then properly create the flavour. Are there off-notes from the protein base to be addressed and masked?

Where are the gaps in both taste and aroma to bring an authentic taste to the product?

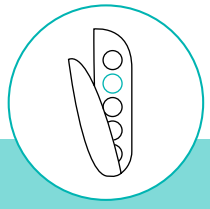
When creating an authentic fish product, it is important to think holistically and consider all aspects, ingredients and interactions. A good starting point is looking at and tasting a gold standard – a perfectly seared piece of yellow-fin tuna for example. Used as a model, this gold standard helps to give guidance as a reference. As the fish is tasted, all elements of the flavour, taste, aroma, mouthfeel, and texture can be considered. Each of these elements will play important roles in the flavour development, as will the application, the type of protein being used, and the cooking process.

Flavour considerations for a great plant-based fish product:



01

Building the taste & body of the basic fish flavour.



02

The likely need for masking tools to counter off-notes from the protein base. For example, in TVP-based analogues such as those with soy or pea proteins, unpleasant off-notes associated with the protein must be overcome.

03

Choosing the right profile reflecting freshness, specific species characteristics etc. For example canned tuna tastes different to fresh tuna and needs a different flavour profile.

04

Using a specific cooking cue to drive the culinary profile. For example, grilled, roasted, or fried.

Culinary concepts

Plant-based fish products lend themselves well to pre-prepared dishes and there is great consumer interest in global flavours from countries where meat is not the main focus. Top flavours for fish dishes include butter, wine and garlic sauces, citrus flavours, especially lime, and chilli.

Spice blends reflecting Asian flavour palettes are popular, such as teriyaki, red and green curry, soy sauce, sweet and sour as well as spicy South American inspired blends such as Chipotle, Jalapeno and Pico de Gallo.

04

Plant-based fish and seafood – the market opportunity

As global fish demand and prices continue to rise there is growing opportunity for plant-based fish to meet the supply gap for real fish products. A competitive price, the absence of bones, as well as being easy to prepare make these products attractive alternatives for consumers.

Studies indicate that there is a growing opportunity in flexitarian households[6]. Here demand is primarily for meat alternatives (more than half of consumers surveyed choose to eat meat alternatives), but this trend indicates a firm shift towards flexitarian lifestyles, interchanging plant-based and animal proteins (only 11% of consumers who chose meat alternatives ate them because someone in the household was vegetarian). As such, this suggests that fish and shellfish substitutes would be an attractive, sustainable alternative for these households.

Last but not least, the increasing numbers of vegetarian and vegan consumers, although still a small proportion of the overall market, are also a growth opportunity.

6) Source: Mintel, Fish and Shellfish, US, 2018

Where to aim – top five consumer fish choices

To identify the best candidates for plant-based product development, we have scored fish and seafood categories using a wide variety of attributes. Scoring attributes included price and demand; environmental impact; and product technology and commercialisation.

The top five products and their subcategories identified were:

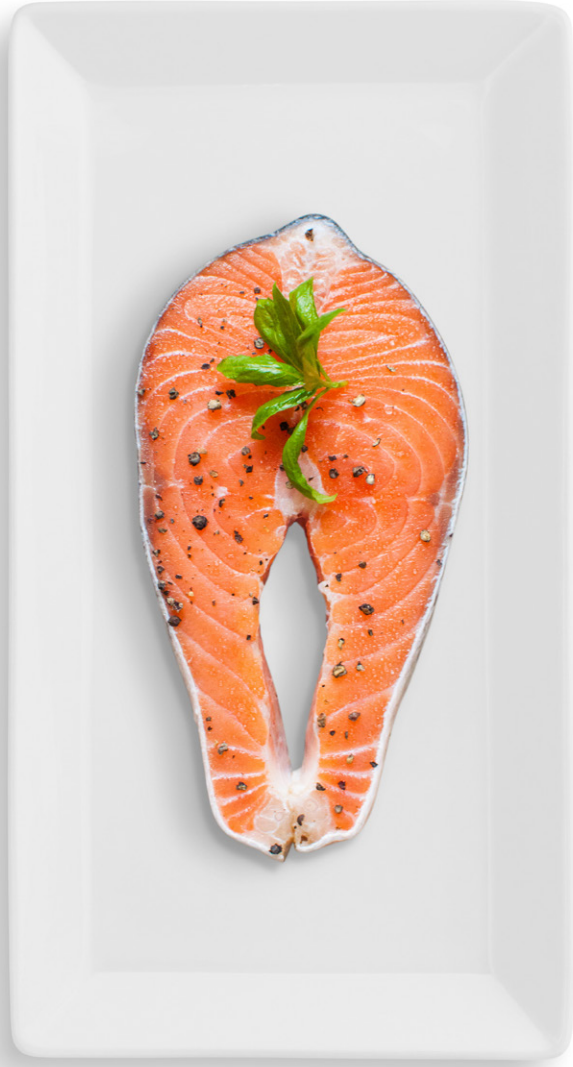
01 Salmon
(smoked salmon, salmon slices)

02 Tuna
(canned tuna, tuna loins)

03 Shrimp
(shrimp nuggets)

04 Crab
(crab meat, crab cakes)

05 Whitefish
(fish fingers, coated fish fillets)



Case studies

Salmon has an almost universal appeal with demand growing across markets globally –

consumption is three times higher worldwide than it was in 1980. Key markets are the US, Japan and the core EU28 countries with demand from emerging markets also growing rapidly. As a result, salmon prices are rising steadily year on year. Farmed salmon accounts for 70% of the entire salmon market but is at risk from diseases and environmental events, such as algal blooms. Consequently supply is vulnerable. Wild catch is limited and remains a small percentage of the overall supply (although previously depleted wild salmon stock is bouncing back to sustainable levels). With high global demand, rising prices, and a vulnerable supply chain salmon presents a major opportunity for plant-based fish. However, texture challenges remain for whole muscle products and so items such as breaded fillets or smoked salmon, present the best opportunity.

Tuna is amongst the most commercially valuable fish in the world,

with high demand and high prices in sushi markets, especially highly prized Bigeye tuna. Overfishing is a particular issue for tuna with around 30% of stocks classed as overfished – particularly Pacific Bluefin tuna, as well as Atlantic Bigeye and Indian Ocean Yellowfin populations. This is increasing year on year, making tuna products a good target for plant-based fish substitutes. However, like salmon, texture is still a challenge, therefore processed tuna products such as canned tuna offer the best opportunity for fish analogues. Furthermore current canned tuna products have yet to successfully replicate the fresh fishy taste of real tuna, presenting a gap in the market ready to be filled.

Shrimp fishing is a highly specialised activity that produces large amounts of bycatch and destroys important habitats

for many species of juvenile fish. Increasingly supply is from farmed shrimp, which accounts for 55% of global production, however, this also has significant environmental impacts, causing wetland destruction and damaging biodiverse habitats. With rising levels of microplastics found in wild shrimp and both wild and farmed shrimp vulnerable to a wide range of pathogens and parasites which are often the cause of food-borne illnesses, cleaner, more sustainable options are highly desirable. Nutritional gap is the key 'watch out' for plant-base shrimp as the ingredients used are often much lower in protein content than other fish analogues. Moulding the more jelly-like structure of plant-based shrimps also presents challenges.

Future-gazing

Plant-based vs lab grown

Cell culture is a likely solution for solving the challenge of recreating whole muscle products. This technology delivers a result that much more closely matches the texture of real fish and seafood. Cultivated products may be the closest, 'freshest' and most nutritional option compared to the real thing and would be very appealing to consumers.

Currently the technology is still in its infancy and there are still ethical, health, product design, texture and regulatory barriers to overcome. But production costs are extremely high and today are not commercially viable at scale. However the technology is advancing all the time and as costs come down these products could be a major market disruptor in the future.

Although at an early stage there are already a number of companies investing in this area. These are mainly based around high-impact biotechnology clusters, for example Finless Foods, Blue Nalu, and Wild Type in Southern California. More widely, companies such as Avant Meats in Hong Kong and Shiok Meats in Singapore are also investing in cell-based fish and seafood development.

Single Cell Proteins (SCP)

Single cell proteins (SCPs) are ingredients derived from algae, fungi, or other microbes that are created using fermentation processes similar to that used in making bread and beer. Bacteria protein have been quite thoroughly explored as an alternative to crops and the process is in use for production of animal feed.

Bacteria proteins are grown via fermentation of optimised strains of microbes and offer high protein content and growth rates. Current downsides include high production cost and potential negative consumer perception, however, this could be a viable alternative in the near future.

Algal proteins are created from algae or seaweed and are currently gaining great interest for plant-based fish and seafood products. Grown in water via photosynthesis this novel protein has quite low production costs. Algae inherently provide a complementary flavour profile for fish and seafood and is a logical, easy-to-understand ingredient for consumers. Initial capital investment is high and growth rates are quite low, so there are still challenges for successful large-scale production.

05

Do you want to be part of the future?

As we have explored in this paper, the opportunity for plant-based fish and seafood is significant and strongly poised for growth. New product development has many complex challenges and companies entering this space need experienced partners with a breadth of tools and capabilities.

As customer and consumer demand in this space increases, Givaudan will continue pioneering holistic solutions in the protein space, driving innovation for food companies and consumers alike.

Contact our experts to find out more
global.protein_solutions@givaudan.com

Givaudan

Let's recreate together the enjoyment of real fish and seafood!