THE RISE OF ALGAE

The Future of Plant-Based Seafood

PRESCOUTER 2023

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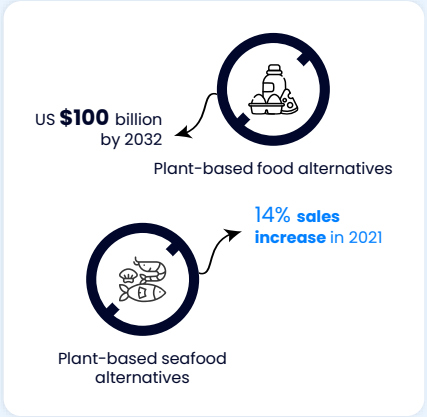
Algae's seafood-like flavor and nutrition are opening up countless opportunities to experiment and create innovative plant-based seafood options.

Sustainability and consumer demand is driving the market growth of plant-based seafood.

The plant-based food market is expected to reach almost US $100 billion by 2032. While plant-based meat, egg, and dairy alternatives are widely accepted, plant-based seafood has also gained momentum with a 14% sales increase in 2021. Plant-based seafood is gaining popularity due to concerns about the negative impacts of traditional seafood on health, the environment, and ethics.



Algae can fill the taste and nutrition gap of soy and pea with a lower carbon footprint.

THE SUSTAINABILITY NEED

Micro- and macro algae are more sustainable to produce and have a lower environmental impact compared to soy and pea, which are often associated with deforestation and monoculture farming.

THE TASTE AND NUTRITION NEED

Algae is a nutritious food source and has a high content of essential vitamins, minerals, protein, fiber, and omega-3 fatty acids. Many types of algae also have a flavor profile that closely resembles seafood due to their umami flavor. Adding a neutral-tasting macroalgae at a high level and a microalgae flavoring agent at a low level can enhance the taste and nutritional value of plant-based seafood.

Novel algae types will pave the way for more R&D opportunities in the plant-based seafood space.

With ~200 different types of seafood, opportunities are endless

The vast array of seafood options that exist in the world presents an exciting opportunity to broaden the range of plant-based seafood products. Algae, with its vast variety and nutritional benefits, opens up countless opportunities to experiment and create innovative plant-based seafood options.

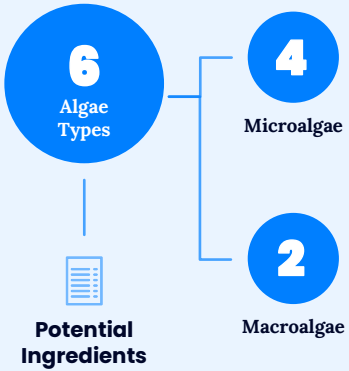
The biggest growth opportunity is in the frozen and chilled sectors

As experts suggest, the frozen and chilled sectors offer great potential for growth in this area.

Approval of novel algae ingredients will increase

In the future, the increasing approval of novel algae types will pave the way for more R&D opportunities in the exciting field of plant-based seafood.

DIVE DEEPER: In this Intelligence Brief, we identify potential ingredients, Centers of Excellence and experts to facilitate partnerships between companies, research institutions, and investors. The plant-based seafood market is in its early stages and requires collaborative efforts to drive progress and advance the industry. Through collaboration, we can accelerate the development and commercialization of innovative plant-based seafood products.



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PRESCOUTER

THE PLANT-BASED SEAFOOD MARKET

A quick overview of the market dynamics, competitive landscape, investments and market drivers

The market for plant-based seafood products is growing rapidly as more and more people become concerned about health, animal welfare, and environmental sustainability.

The plant-based foods market has experienced rapid growth in recent years, with **over 6485 new plant-based products** introduced worldwide between 2015 and 2020.

The **global plant-based food market** reached USD 42.8 billion in 2022 and is projected to expand to approximately **USD 99.7 billion by 2032**.

As of 2023, **about 60% of younger generations** (Gen Z and Millennials) are on the front lines of society's response to climate change and believe that is mostly caused by human activities. Hence, **many of these consumers are turning to plant-based products** as a way to reduce their carbon footprint and mitigate the environmental impact of animal farming.

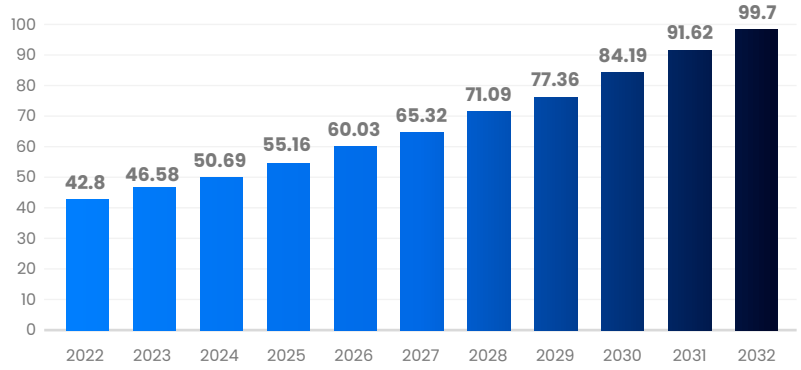


Figure. Projected plant-based food market size 2022-2032 (in USD Billion). Source: Precedence Research.

3x

Plant-based food sales grew three times faster than total food sales in 2021.

Source: Good Food Institute.

Plant-based seafood is less developed compared to plant-based meat/dairy/egg products, but is poised to see rapid growth.

The urgency to create seafood alternatives may be relatively low because:

- Compared to plant-based meat, egg, and dairy products, seafood is often **perceived as a healthier and more sustainable** source of protein compared to meat; and,
- The **taste and texture of seafood can be more challenging to replicate** using conventional plant-based ingredients.

Despite these challenges, plant-based seafood products experienced **significant growth**, **with a 14% increase in sales in 2021**, outpacing the growth of plant-based meat sales.

This growth could be attributed to several factors. For instance, consumers are becoming increasingly aware of the environmental impact of seafood production, as well as concerns over mercury contamination and overfishing.

Therefore, if the plant-based seafood captures the same market share as plant-based meat, **plant-based seafood can reach up to $220 million in retail only!** However, given that the majority of seafood sales occur in foodservice, the total market potential for **plant-based seafood is likely to be significantly higher and experience rapid growth**.

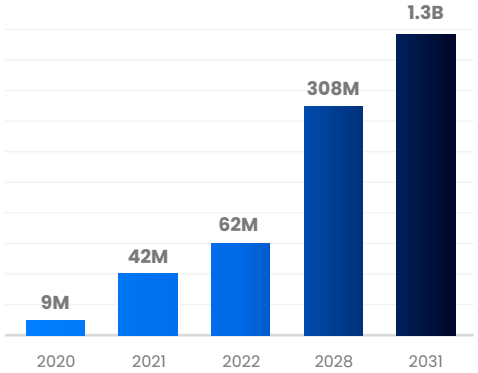
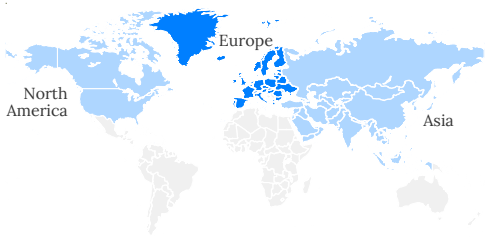


Figure. Global market (USD) of plant-based seafood. Predictions indicate that the global market can reach USD 1.3 billion in 2031.
Source: Allied Market Research, Imarc Group.

North America and Europe have become the global leaders of the plant-based seafood market.

In 2021, Europe was the largest market for plant-based seafood, holding approximately 40% of the global sales, followed by North America and Asia.



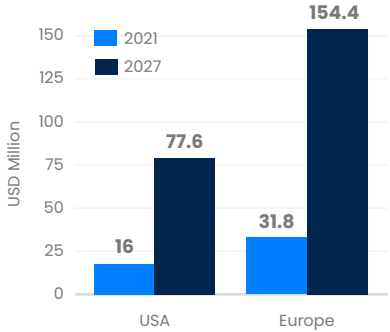
Examples of major companies operating in plant-based seafood.

Plant-based fish accounts for

>60%

of the global plant-based seafood market

The projected value of the plant-based seafood market in North America, based on the US market alone, is expected to reach USD 77.6 million by 2027, which is nearly half of the estimated value for Europe in the same year, forecasted to be USD 154 million.



Changes in consumer behaviour, innovation, and investments are fueling the rapid growth in the plant-based seafood market.

The rise in demand for **clean label**, **ethical**, **sustainable**, and **organic** products, along with the growing demand for food and beverage due to **population growth**, are driving factors for the plant-based seafood market.

Additionally, consumers are increasingly **conscious of the health and environmental benefits** associated with plant-based diets.

Plant-based seafood products can also be **safer options for consumers who are allergic to shellfish**.

As a response to the changes in consumer behaviors, a higher number of companies and investors in the food and beverage industry are becoming more interested in plant-based alternatives due to the growing demand for these products.

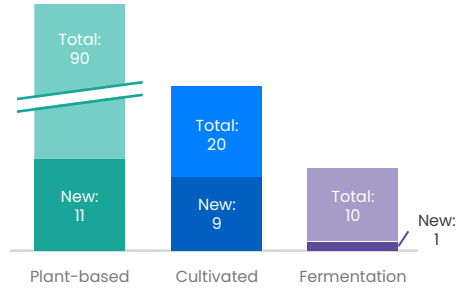
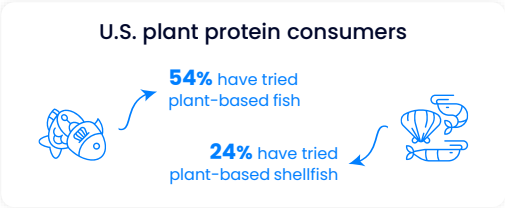
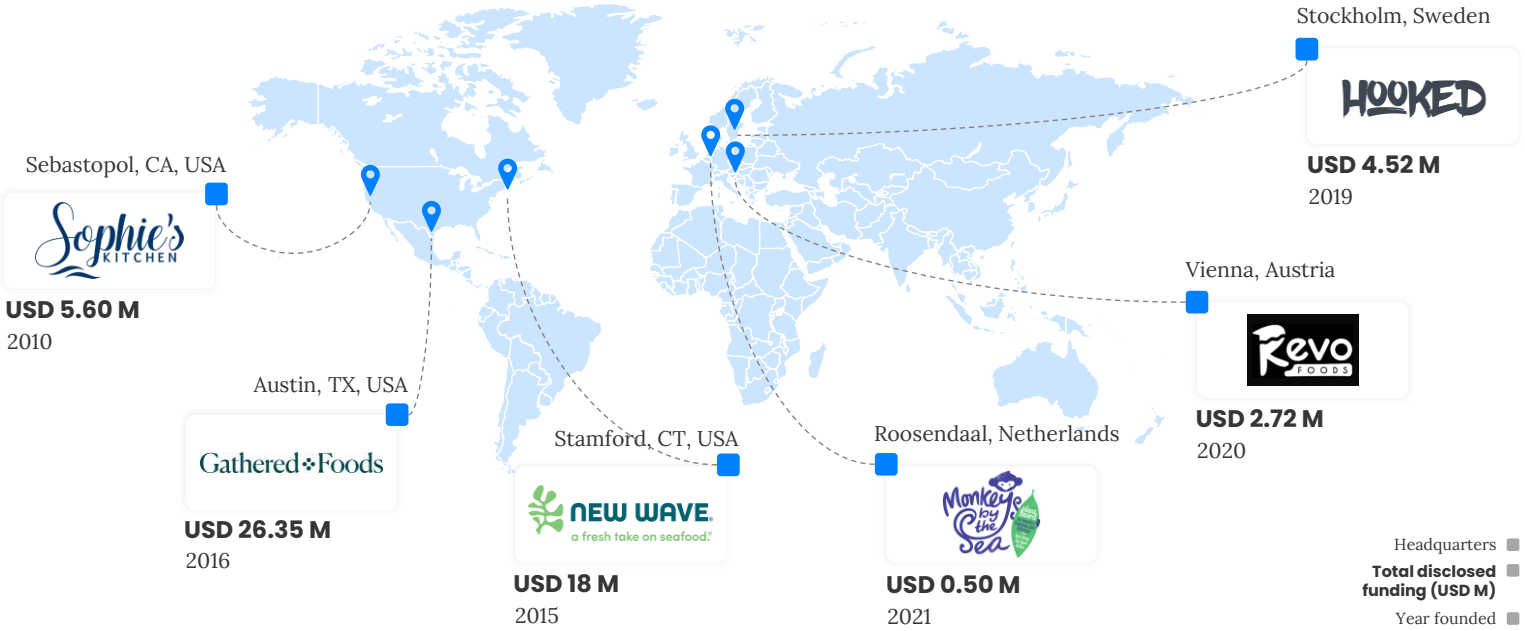


Figure. Companies developing alternative seafood in 2021. Source: Good Food Institute.



In 2021, there were **141 companies** developing plant-based, fermentation-derived, and cultivated seafood products around the world.



2021 Investments in plant-based seafood companies with disclosed deal sizes. Source: Good Food Institute.

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> Though seafood has traditionally been perceived as a healthier and more environmentally friendly option, recent documentaries such as Seaspiracy have shed light on the environmental and ecological costs associated with seafood production, prompting consumers to reevaluate their choices.

Ida Speyer
Co-founder and CEO,
Mimic Seafood

> While the plant-based meat market is more established for red meat, there is currently a growing interest in plant-based seafood due to the introduction of innovative new products.

Maarten Geraets
Managing Director of Alternative Proteins, Thai Union Group PCL

Click here to read full interview

The plant-based seafood market offers opportunities for innovation by focusing on improving flavor, nutrition, and sustainability.

Current plant-based seafood products lack the **flavor** and **quality** that real seafood offers due to the complex compounds needed to replicate its taste and aroma, such as polyunsaturated fatty acids (PUFAs), sulfuric compounds, and nitrogen-containing compounds.

The nutritional benefits of current plant-based seafood alternatives may not match those of animal and fish-based foods, highlighting the need for improvements in plant-based food fortification to enhance their **nutritional profile**, particularly in regards to **protein content**.

Most current plant-based seafood products utilize conventional proteins such as **soy and pea**, which may not be the most sustainable option due to the use of agrochemicals in their production, leading to **soil and water pollution**.

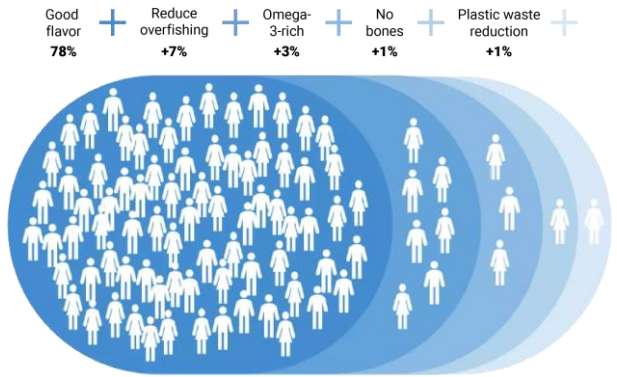

Figure. Majority of consumers believe that flavor is the most important factor in choosing alternative seafood over conventional seafood. Source: GFI.

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> Unlike burgers or hotdogs, seafood's delicate flavors can be challenging to enhance without overpowering. R&D faces the unique challenge of elevating seafood's natural taste without drowning it in strong flavors. Plant-based seafood also needs to be healthy and not too synthetic to compete in the market.

Ida Speyer
Co-founder and CEO,
Mimic Seafood

> Developing exciting seafood alternatives that satisfy both taste and nutritional needs is a priority. However, cost, taste, texture, and scaling up production remain significant challenges.

Maarten Geraets
Managing Director of
Alternative Proteins,
Thai Union Group PCL

Click here to read full interview

Plant-based seafood offers a sustainable alternative to traditional seafood, and could help address global hunger and protect wild fisheries and ecosystems.

global population will requires a **70% increase** in food production by **2050**

more than 34% wild fisheries are already overfished

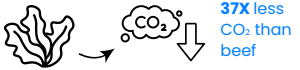
threat to global food security

1.5 billion kg CO_2

CO_2 from unsustainable industrial fishing practices

5 to 10 times lower than tuna and salmon production

carbon footprint of plant-based food production



37X less CO_2 than beef

microalgae fermentation, a promising protein technology

The global population increase requires a 70% increase in food production by 2050, with a demand for approximately 202 million tonnes of protein. As of 2021, there were 828 million people at risk of malnutrition.

However, with more than 34% of wild fisheries already overfished, this poses a significant threat to global food security, as fish populations continue to decline rapidly.

In addition, unsustainable industrial fishing practices such as “bottom trawling” which accounts for 25% of all wild-caught seafood, releases 1.5 billion kilograms of carbon dioxide into the atmosphere annually.

Plant-based food producers have lower carbon footprints compared to traditional animal-based food producers. The carbon footprint of plant-based food production is 5 to 10 times lower than that of tuna and salmon production.

Additionally, microalgae fermentation is a promising protein technology that has been shown to produce 37X less CO_2 than beef.

When considering all factors, plant-based seafood emerges as an alternative to alleviate the pressure on both wild fisheries and aquaculture systems.

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> As seafood becomes scarcer due to overfishing, habitat destruction, and pollution, the cost will inevitably rise. However, this comes at a high price, as we risk not only the loss of entire species, but also the contamination of our food with harmful substances.

Ida Speyer
Co-founder and CEO,
Mimic Seafood

> Health concerns and the desire for more food choices are driving the growth of seafood alternatives. By creating new and exciting seafood experiences, we can expand the variety and offerings available increasing overall seafood consumption. Innovative seafood alternatives can address allergies, mercury, and microplastic concerns for consumers.

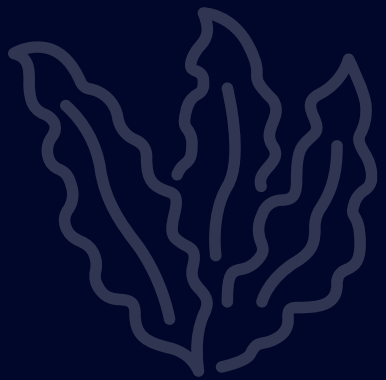
Maarten Geraets
Managing Director of
Alternative Proteins, Thai
Union Group PCL

Click here to read full interview

ENTER ALGAE: THE NEW FRONTIER

A look at what makes algae such an attractive ingredient for plant-based seafood.

Algae, as a key ingredient in plant-based seafood, offers a distinctive taste profile and is rich in essential fatty acids and proteins.



Microalgae and macroalgae (aka seaweed), are abundant in **proteins**, **soluble fibers**, and **bioactive compounds** such as polysaccharides, lipids, polyunsaturated fatty acids, pigments, vitamins, and minerals. Therefore, their biomass can serve as a valuable ingredient in food production, satisfying the demand for nutritious, sustainable, and health-promoting food among consumers.

Microalgae with **high protein content** (typically ranging from 28% to 71% of dry weight) may contain a substantial amount of free **amino acids**, which can contribute to the **umami taste**, a defining attribute of seafood. Some species, such as *Arthrospira platensis* (Spirulina) and *Chlorella vulgaris*, are particularly promising with protein content ranging from 50% to 60% based on dry weight.

Algae is viewed by experts as an appropriate alternative to fish and shellfish due to its unique taste profile, which varies from **umami**, **salty**, **grassy**, to **nutty**. Additionally, it can provide a substantial amount of the necessary **omega-3 fatty acids** for human diets, thereby decreasing the need for fish consumption.

Various companies are now broadening their horizons by producing seafood products using **seaweed**. Some examples include: New Wave, Mara Seaweed, and Gimme. The developments in the algae industry can be followed on Algae Planet.

Algae is a rich source of compounds that impart a seafood-like flavor.

Depending on the concentration of each component, the resulting flavor may differ slightly.

The figure on the right highlights the most common compounds found in algae that mirror the seafood flavor profile. However, it's important to note that certain compounds like hexanal and heptanal can contribute to a grassy note in algae, and an excessive amount of these compounds could result in an undesirable flavor for plant-based seafood.

While specific compounds play a significant role in particular seafood tastes, it's crucial to maintain a well-balanced amount of each component to achieve the most authentic flavor profile that consumers crave. In the following sections, we'll delve deeper into various types of algae known to embody the flavor of different seafood types.

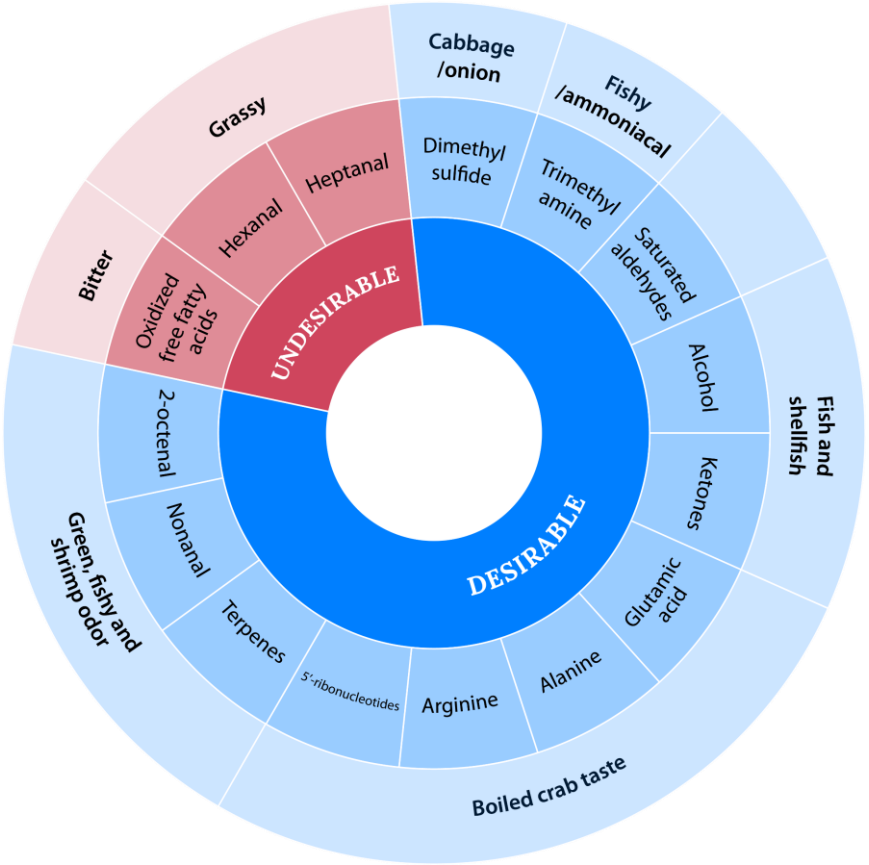


Figure. Common compounds found in algae that resemble the taste of seafood. References: 1 & 2.

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Three experts weigh in on the potential of algae to disrupt the plant-based seafood Industry

Ida Speyer

Co-founder and CEO,
Mimic Seafood

Ida Speyer is the CEO and co-founder of Mimic Seafood, a plant-based seafood company based in Madrid, Spain. She has extensive experience in the plant-based sector and as a startup founder, and is highly committed to projects that help solve climate-related issues. She is a founding member of Skovshoved Ocean Garden and owner of Ocean Greens.

Maarten Geraets

Managing Director of Alternative Proteins, Thai Union Group PCL

Maarten Geraets is the Managing Director of the newly created Alternative Protein business unit at the Thai Union Group in Thailand. He oversees the development and growth of Thai Union's alternative protein portfolio, including plant-based seafood. Under his leadership, Thai Union has expanded its presence globally in the alternative proteins market and is committed to providing sustainable and healthy food choices for consumers.

Johan Robbens

Head of Cell Blue Biotech and Food Integrity, Flanders Research Institute for Agriculture, Fisheries and Food (ILVO)

Johan Robbens is the Head of Cell Blue Biotech and Food Integrity at ILVO, an independent research organization in Belgium that supports scientific research in the areas of agriculture, fisheries and food. He is currently conducting research on the valorization of marine resources including seaweed and microalgae. He coordinates the ValgOrize project, which focuses on the valorization of algae for food and feed, with a particular emphasis on taste to drive acceptance of plant-based food.

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Ida Speyer

Co-founder and CEO,
Mimic Seafood

Maarten Geraets

Managing Director of
Alternative Proteins,
Thai Union Group PCL

Q: Why has plant-based seafood received less research and investment compared to plant-based meat, eggs, and dairy which have experienced significant growth in the last few years?

Ida Speyer:

It's a combination of different factors. The drive for plant-based dairy and beef was the first and the strongest because of the connection of CO2 and health. There's a high CO2 cost for producing dairy and beef and there are also a lot of health implications associated. These are easy drivers for consumers to understand. Consumers perceive seafood as a healthier product with less environmental impact. However, we now see it in waves with Seaspiracy and other documentaries where you see that there is actually a huge environmental and ecological cost with seafood.

Maarten Geraets:

There was a greater need from a nutritional perspective to focus on red meat, but people are now realizing that there is a valid opportunity across the board. Meat is at least 10 years ahead of seafood in terms of plant-based alternatives. However, there is currently a lot of excitement in the plant-based seafood market due to new innovations and products being introduced.

> **I think plant-based is the only way we will have food in the future. I think it's just going to be a transition that takes some time.**
>
> - Ida Speyer

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Ida Speyer

Co-founder and CEO,
Mimic Seafood

Maarten Geraets

Managing Director of
Alternative Proteins,
Thai Union Group PCL

Q: What do you think are the biggest drivers for the plant-based seafood market?

Ida Speyer:

I think cost will be a huge driver. Seafood is becoming scarce. We're emptying the oceans. We're eliminating entire species of fish. We're destroying their habitats. We're polluting so much that fish now contains plastic and heavy metals. Therefore, I think the fact that there will be less and less fish will drive up the cost, and at the same time, with pollution, fish may even not be safe to eat anymore in the future.

Maarten Geraets:

One driver is health, such as "allergies." People have allergies for shrimp for example. There are indeed concerns on certain segments of the population around mercury and microplastics.

The big driver is that people want more choices and this is an opportunity that we can provide.

We started off mimicking existing fish types similar to what was done in meat, but I don't think that is where it ends. I think it will go beyond that. You will create new seafood experiences that would excite people. The ambition is to grow the overall consumption of seafood, expanding the variety and offerings available. I'm not just referring to traditional seafood, but also innovative alternatives.

EXPERT Insights

Ida Speyer

Co-founder and CEO,
Mimic Seafood

Q: What do you think are the major challenges in developing plant-based seafood?

Ida Speyer:

A huge challenge in R&D is that usually when you eat fish and seafood you don't drown it in strong flavors. For example, when you eat a hotdog or a burger, you might add ketchup, mustard, pickles, and spicy sauce to enhance the flavor, and the end result will be dominated by the taste of the condiments, rather than the original flavor of the food itself.

With fish, maybe you sauté it or you bake it but you're very light on the flavors. It's very delicate. You try to just accentuate the fishy flavor so your product really needs to be good because it's not going to be covered in BBQ sauce or deep fried. And that is why we have to spend a bit more time in R&D.

Also, the fact that people do consider fish as healthy also means that if you want to compare and compete you need a product that doesn't contain too many artificial flavors so it's not too synthetic. It needs to be pretty healthy as well.

> **R&D for fish and seafood is a challenge because their delicate flavor must be accentuated without drowning it in strong condiments. This requires extra effort and time to create a quality product that is also healthy and not too synthetic.**
>
> - Ida Speyer

EXPERT Insights

Maarten Geraets

Managing Director of
Alternative Proteins,
Thai Union Group PCL

Q: What do you think are the major challenges in developing plant-based seafood?

Maarten Geraets:

I think foremost that we need to develop products that excite consumers. Mimicking is a start, but also a challenge because it will never be the same. We seek new seafood experiences beyond this, as we take consumers on a journey. It has to be a great tasting protein solution that provides you with your needs from a protein, satisfying both taste and nutritional requirements.

A challenge from the development side is “cost.” These products today are still more expensive than traditional protein. Moreover, taste, texture and aroma remain a challenge with seafood. We are not dealing with chicken. We have 200 different species in seafood. The flavors are more subtle in most cases, the color is more varied from stark white to pinkish to brown, and textures have more complexity and variety.

Furthermore, scaling up production is a major challenge in plant-based seafood.

> **Taste, texture and aroma remain a challenge with seafood. We are not dealing with chicken. We have 200 different species in seafood. The flavors are more subtle in most cases, the color is more varied and textures have more complexity and variety.**
>
> - Maarten Geraets

EXPERT Insights

Ida Speyer

Co-founder and CEO,
Mimic Seafood

Maarten Geraets

Managing Director of
Alternative Proteins,
Thai Union Group PCL

Q: What are your thoughts on using microalgae or seaweed in plant-based seafood products?

Ida Speyer:

I'm a huge fan of seaweed and microalgae. They are incredible. They are very sustainable to produce. They actually combat climate change in production. If you grow them naturally in the oceans, they're providing habitat. Therefore, I think we should really look into more ways of incorporating macro and microalgae in our product developments.

In Mimic, we do already use different kinds of seaweeds for flavoring. Our fishy flavor comes from natural ingredients such as nori and kombu. These kinds of seaweeds have a nice ocean flavor. Also, microalgae can be very good for nutritional purposes. It has a lot of protein but really healthy protein and has the omegas. There are a lot of companies now working on white and yellow chlorella which is really exciting because it doesn't have the flavor that green chlorella has, but then also the nutritional profile is different. There is still a lot to be done from ingredient companies to really unlock the potential of these algae.

Maarten Geraets:

The use of sea plants in food products can be marketed to consumers with more compelling storytelling compared to land-based plants, and can provide unique nutritional benefits and natural seafood flavors. It also sets itself apart from meat-based products. There is a huge opportunity in this space.

EXPERT Insights

Johan Robbens

Head of Cell Blue Biotech and Food Integrity, Flanders Research Institute for Agriculture, Fisheries and Food (ILVO)

Q: What are your thoughts on using microalgae or seaweed in plant-based seafood products?

Johan Robbens:

We have done a lot of consumer testing with microalgae and see that taste is a real driver. There are official reports from institutions stating that people may not like the taste of algae-based products. However, I believe this may be attributed to the wrong choice of algae. Upon assessing the algae profile, I found that there are certain types of algae with excellent seafood profiles. There are also a lot of health benefits with algae.

Our idea is to combine algae that provides a great seafood taste at a lower level (0.5% to 2%) with a neutral-tasting macroalgae/seaweed at a higher percentage that provides the necessary nutritional benefits.

In regard to sustainability, we are looking to recycle the waste water from growing algae and reuse that for the growth medium.

EXPERT Insights

Johan Robbens

Head of Cell Blue Biotech and Food Integrity, Flanders Research Institute for Agriculture, Fisheries and Food (ILVO)

Q: Are there any challenges with adding algae in plant-based seafood?

Johan Robbens:

It is important to grow the algae under the correct conditions to develop the right flavor in the algae. Processing and storage can also affect the taste profile. For example, powders are often used in the food industry and are made by drying. Drying at a higher temperature (60°C) can remove the volatile compounds. Drying and storing at low temperatures is crucial.

For example, umami is an important taste aspect of seafood. We can adjust our nutrients for the algae to have a greater umami taste.

Many algae have a seafood profile, but some have other flavor profiles such as flour taste that can be used for sweet foods, and it's important not to frame microalgae only as a seafood alternative as they can also be used for other tastes.

Another challenge is that only one type of algae currently has the status of novel food in Europe, despite many more algae being in development. However, Europe is investing a lot of money in algae research and had recently set up a platform called EU4Algae because everyone has realized the big potential with algae. Together with European Authorities, we are looking to see how we could improve and make the approval process more efficient.

EXPERT Insights

Ida Speyer

Co-founder and CEO,
Mimic Seafood

Maarten Geraets

Managing Director of
Alternative Proteins,
Thai Union Group PCL

Q: Are there any challenges with adding algae in plant-based seafood?

Ida Speyer:

One limitation right now is that it is still quite expensive especially if you compare it with soy and pea protein. It is a common early stage limitation. Once more and more companies use these ingredients, the prices will probably go down.

It is also important to note that using a single ingredient in large quantities, such as nori or kombu, could lead to unsustainable monocultures in the ocean, similar to those seen in agriculture. It is important to avoid repeating past mistakes and use a variety of ingredients to increase resilience in the food system.

Maarten Geraets:

There are many non-discovered algae types out there. To get approval for these novel ingredients it will take time. There's a lot of work to be done getting regulatory approval, getting the sourcing right, and getting the value chain in place.

EXPERT Insights

Ida Speyer

Co-founder and CEO,
Mimic Seafood

Maarten Geraets

Managing Director of
Alternative Proteins,
Thai Union Group PCL

Q: Could you please share any insights on the current trends and growth opportunities within the plant-based seafood market, and whether there is a specific product segment that you see as particularly promising or rapidly growing?

Ida Speyer:

Overall, convenience food is experiencing massive growth across all categories, not just in plant-based options, but also in healthy, unhealthy, kid-friendly, gluten-free, and more. All of these different variations of convenience food are growing very rapidly. I believe that healthy snack foods that are easy for people to prepare quickly, such as frozen or chilled food that can be cooked in two minutes in a microwave or oven, will be a growing category. Of course, there is also a market for plant-based seafood, as it is a consumer trend that is growing rapidly.

Maarten Geraets:

You have 200 different types of seafood, such as different cuts of tuna and various shrimp varieties, providing a much wider range of offerings. While there is still catching up to do in comparison to the meat category, I believe we can accelerate and catch up much faster, as a lot of the groundwork has already been laid by the meat industry. It took 10 years for customers to become familiar with plant-based burgers, but introducing plant-based tuna would be an easier sell. Looking ahead, I believe our opportunity lies in the frozen and chilled (refrigerated) sector.

EXPERT Insights

Ida Speyer

Co-founder and CEO,
Mimic Seafood

Q: What do you think the future looks like for the plant-based seafood market?

Ida Speyer:

I think we will see some startups graduate into global enterprises. Some major food companies might absorb some startups and technologies or bring their own version out similar to how Nestlé has a small plant-based seafood portfolio. The meat and dairy companies have done it already with their own brands and versions. I think the same will happen with seafood. This will make it easier for consumers because prices will be lower and availability will be very high. This will move from niche to mainstream.

It will also be interesting to see what happens now as the global economy slows down a bit, because we saw that there was a huge surge of interest for plant-based during COVID. I think a lot of plant-based products are cheaper than the animal-based equivalents. Plant-based dairy is getting very cheap. I am very curious to see if saving money would actually be a second driver for plant-based or if people would become more traditional and return to what they are familiar with.

EXPERT Insights

Maarten Geraets

Managing Director of
Alternative Proteins,
Thai Union Group PCL

Q: What do you think the future looks like for the plant-based seafood market?

Maarten Geraets:

I think the future is very bright, although it may take longer than some investors had anticipated at the beginning. The main problem is that many people outside of the industry assumed that people would adopt new food habits as quickly as they adopt new technologies like iPhones, but that is not the case. Changing food habits is much more complicated because there is much more emotion attached to it.

> **Currently, we see much better traction in Europe than in the US. I believe that even markets in the Asia-Pacific region, which are currently lagging behind the US and Europe, will catch up soon. Europe seems to have better quality products in the market at the moment. It is a consumer mindset change that needs to happen. The market is globally barely 1% of traditional meat and seafood, where meat is far ahead. It will take time but it is going to happen.**
>
> - Maarten Geraets

Joining Forces for a Better Future:
Collaborative Efforts in the Plant-Based Seafood Industry

> What I really appreciate in this new space with alternative proteins is that there is no more “us” vs “others.” It is more about how we are growing this category together. We are seeking partners across the value-chain to deliver better products in a joint effort. Everybody realized that the challenge is too big to have it on your own. You need to join forces.

Maarten Geraets
Managing Director of Alternative Proteins, Thai Union Group PCL

> It is a very collaborative industry. We have a lot of internal communication between different companies because we are early stage. It is really valuable for us that we actually share with other companies. We share experiences and knowledge about some ingredients. Right now we are just trying hard to grow the category and showcase the benefits of these products to new consumers.

Ida Speyer
Co-founder and CEO, Mimic Seafood

Click here to read full interview

COLLABORATION OPPORTUNITIES

Centers of Excellence and Experts

Back to the Executive Summary

Select Centers of Excellence (CoE)

As the demand for sustainable and ethical food options continues to rise, it is evident that the plant-based seafood industry holds tremendous potential. However, for this industry to flourish, it is crucial to identify and collaborate with Centers of Excellence and affiliated experts who can provide the necessary resources, knowledge, and expertise. In this section, we delve into some of the leading organizations that are spearheading plant-based seafood research, development, and innovation.

CoE	Organization Type	Rationale for inclusion	Associated Experts
TECHNION Israel Institute of Technology	Academia	Technion is engaged in multiple collaborative projects with other institutions aimed at developing seafood alternatives, and boasts exceptional researchers specializing in algae-based proteins.	Yoav D Livney, Ph.D.
UMASS	Academia	The University of Massachusetts is actively engaged in various research projects related to plant-based seafood, with a number of accomplished experts working in this field.	David Julian McClements, Ph.D., Jiakai Lu, Ph.D.
	Academia	The University of Minho has been known to have active research programs in the field of biotechnology and food science, including the development of plant-based seafood alternatives and the use of microalgae and macroalgae as sustainable protein sources.	Cristina M. R. Rocha, Ph.D.

Select Centers of Excellence (CoE)

CoE	Organization Type	Rationale for inclusion	Associated Experts
gfi Good Food Institute	Nonprofit Organization	The Good Food Institute (GFI) is one of the top nonprofit organizations dedicated to conducting research on plant-based meat and seafood. They have established multiple partnerships with institutions to promote scientific advancements in alternative seafood.	Marika Azoff
ILVO Flanders Research Institute for Agriculture, Fisheries and Food	Nonprofit Organization	The Flanders Research Institute for Agriculture, Fisheries and Food (ILVO) is an independent scientific research institute that is actively engaged in developing research on the seaweed/algae food chain.	Johan Robbens, Ph.D.
Protein Industries Canada	Global Innovation Cluster	Protein Industries Canada is a not-for-profit, industry-led organization that aims to establish Canada as a leading global source of high-quality plant protein and plant-based co-products.	Bill Greuel, M.Sc.
ROTHAMSTED RESEARCH	Nonprofit Organization	Rothamsted Research is a research center that specializes in sustainable agriculture and crop science. Among its various research projects, the center is working on the production of fish oils (such as Omega-3) from microalgae.	Johnathan Napier, Ph.D.

Experts from Centers of Excellence

David Julian McClements, Ph.D.

Distinguished Professor,
University of Massachusetts

Profile: Link **Current working status:** Employed

mcclements@foodsci.umass.edu

(413) 545-2275 Massachusetts, United States

Dr. McClements is an expert in the area of food texture, flavor and nutrition and is currently developing research on the use of alternative proteins to produce seafood analogs. He also has great experience on plant-based nanostructures, methods for testing the quality attributes of plant-based foods, quantification of vitamins in plant-based foods and several other areas.

One of his publications related to plant-based seafood is the "Production of Plant-Based Seafood: Scallop Analogs Formed by Enzymatic Gelation of Pea Protein-Pectin Mixtures."

Jiakai Lu, Ph.D.

Assistant Professor,
University of Massachusetts

Profile: Link **Current working status:** Employed

jiakailu@umass.edu

(413) 577-7194 Massachusetts, United States

Dr. Lu is an expert in food process engineering. He is currently developing a technology for plant-based seafood to better mimic the texture of fish meat, using a coating approach with bio-ink to reproduce the laminated structure of fish fillets. He also has great experience with nanostructured foods for improved sensory attributes, as well as the functional role of plant proteins.

Besides working with Dr. McClements on the plant-based scallop analogs project, Dr Lu had also published a literature review on the Functional Performance of Plant Proteins.

Experts from Centers of Excellence

Marika Azoff

Senior Corporate Engagement Specialist,
Good Food Institute (GFI)

Profile: Link **Current working status:** Employed

marikaa@gfi.org

(866) 849-4457 New York, United States

Marika is the Corporate Engagement Specialist at The Good Food Institute. She has experience in the private sector, working to accelerate the development of alternative seafood and animal conservation in the last decade. She is the author of multiple GFI reports related to alternative seafood.

Cristina M. R. Rocha, Ph.D.

Researcher,
University of Minho

Profile: Link **Current working status:** Employed

cmrocha@ceb.uminho.pt

(253) 604 423 Braga, Portugal

Dr. Rocha is a highly experienced expert in food biotechnology, with a particular focus on extracting bioactive and texturizing ingredients from algae. These ingredients have significant potential for developing plant-based seafood products, including aroma compounds, proteins, and polysaccharides..

Experts from Centers of Excellence

Yoav D Livney, Ph.D.

Professor,
Technion

Profile: Link **Current working status:** Employed

livney@technion.ac.il

(972) 48294225 Haifa, Israel

Dr. Livney is a renowned expert in protein extraction from algae and the texturization processes used to create plant-based seafood from protein-rich seaweed extracts. He has authored over 70 scientific publications and holds nine patents.

Johan Robbens, Ph.D.

Director of the Blue Biotech/Food Integrity unit, Flanders Research Institute for Agriculture, Fisheries and Food (ILVO)

Profile: Link **Current working status:** Employed

johan.robbens@ilvo.vlaanderen.be

32 (0)59 56.98.50 Merelbeke, Belgium

Dr. Robbens is currently conducting research on the valorization of marine resources including seaweed and microalgae, with the aim of finding optimal growing conditions that will ensure they have a good taste for use in food. He coordinates the ValgOrize project, which focuses on the valorization of algae, microalgae, and macroalgae for food and feed, with a particular emphasis on taste to drive acceptance of plant-based food. He also conducts research on contaminants in the marine environment, including microplastics in food, which is relevant to the production and safety of plant-based seafood.

Experts from Centers of Excellence

Bill Greuel, M.Sc.

Chief Executive Officer,
Protein Industries Canada

Profile: Link **Current working status:** Employed

bill@proteinindustriescanada.ca

(306) 949-0049 Saskatchewan, Canada

Bill is the Chief Executive Officer of Protein Industries Canada. He leads several programs, resources and initiatives related to alternative protein development. Bill and Protein Industries Canada work with various partners, including businesses, academic institutions, and government agencies, to fund and support research, innovation, and commercialization in the plant protein sector.

Johnathan Napier, Ph.D.

Professor / Flagship Leader,
Rothamsted Research

Profile: Link **Current working status:** Employed

johnathan.napier@rothamsted.ac.uk

(0) 1582 938 136 Harpenden, England

Dr. Napier is a distinguished specialist in plant biotechnology and the biosynthesis of omega-3 long chain polyunsaturated fatty acids. He is currently leading cutting-edge research projects centered on the production of omega-3 from genetically-engineered plants, as well as the extraction of oils from algae.

COLLABORATION OPPORTUNITIES

Grants & Tech Transfer Opportunities

Back to the Executive Summary

FUNDER

Grant Link
gateway@ukri.org
Swindon, England

SUMMARY

Grant recipient

Born Maverick Vegan Beverages Ltd

Funded period

Nov 20, 2022 - Jun 21, 2022

Funded value

£69,066

Project status

Closed

Grant

Developing Atlantic seafood alternatives from seaweeds within Northern Ireland through sustainable reverse engineering techniques following post Covid-19 Trends

Project overview:

The project aims to:

- identify seaweeds within North Ireland with nutritional properties similar to prawns,
- create the same taste, texture and compatibility similar to prawns from them, and
- optimize upscaling through sustainable packaging and shelf life development.

FUNDER

Grant Link
Contact Page
Europe

SUMMARY

Program

Horizon Europe Framework Programme (HORIZON) 2023-2024

Open period

Oct 17, 2023 - Feb 22, 2024

Total budget of the Program

€12.4 billion

Grant

Impact of the development of novel foods based on alternative sources of proteins

Project overview:

The project aims to:

- evaluate new protein sources (e.g., insects, algae, microbes, food/aquaculture by-products) for sustainable food systems,
- involve a wide range of food system actors and conduct interdisciplinary research,
- encourage international cooperation to collaborate with other relevant projects and participate in joint activities, workshops, and common communication and dissemination activities.
- evaluate the economic, social, and environmental impact of the final products compared to conventional sources of proteins
- deliver co-benefits for climate, biodiversity, environmental sustainability, and circularity.

FUNDER

Grant Link

Dr. Hongda Chen | (202) 445-5582
hongda.chen@usda.gov

North America

SUMMARY

Program

Agriculture and Food Research Initiative
Competitive Grants Program
Foundational and Applied Science Program 2023-2024

Application deadlines

Sept 28, 2023
Sept 26, 2024

Grant award

$650,000 for Standard Grants, Strengthening Standard Grants and New Investigator Standard Grants
$800,000 with specific partnerships
$300,000 for all Seed Grants
$50,000 for Conference and Equipment Grants

Grant

Novel Foods and Innovative Manufacturing Technologies

Project overview:

The Program focuses on Novel Foods and Innovative Manufacturing Technologies (Program Area 3b), making it highly relevant for alternative protein research.

The program considers newly developed food products and ingredients produced using innovative technologies or processes such as cell-cultured meat, seafood, and animal proteins, plant-based protein products, edible insect proteins, single-cell proteins, and other novel sources/varieties.

The project aims to:

- improve food manufacturing competitiveness for a sustainable, healthy food supply.
- enhance knowledge of novel foods, such as cell-cultured meat, seafood, and plant-based proteins,
- develop innovative, efficient manufacturing technologies, and
- improve the quality, safety, nutrient profile, and shelf-life of these foods and reduce food waste across the supply chain, with a focus on a circular bioeconomy.

FUNDER

Tech Transfer Link
tto@umass.edu
Amherst, Massachusetts, USA

SUMMARY

Lead Inventor

David Julian McClements

Availability

Available for Licensing and/or Sponsored Research

Patent Status

Patent pending

Contact Person

Ling Shen, Senior Licensing Officer, University of Massachusetts
lxshen@research.umass.udu | 413-545-5276

Grant

Plant-based seafood and method of Making Thereof

Project overview:

An innovative method is proposed to produce plant-based seafood analogs (fish, scallops, foie gras, and shellfish) from non-animal protein sources and polysaccharides. The final product has an appearance, texture and water holding capacity that mimic those of real seafood. The similarity between the proposed plant-based product and real seafood was confirmed by microscopic analysis and bulk physicochemical properties.

The project has the following advantages:

- safety and sustainability of the plant-derived ingredients used,
- absence of seafood and soy allergens in their composition,
- simple manufacturing process that does not involve expensive or energy-intensive equipment.

SIX NOVEL ALGAE INGREDIENTS

Back to the Executive Summary

Algae Solutions from Academia

	Scientific Name	Key Flavor enhancement (flavor, taste, and aroma)	Applicable type of plant-based seafood
Microalgae	 *Rhodomonas salina*	High umami and seafood taste, crab fish and mussel aroma	Crab, fish and mussel
Microalgae	 *Tetraselmis chui*	High fishy and umami taste, crab and mussel aroma	Prawn and mussel
Microalgae	 *Phaeodactylum tricornutum*	Aroma taste and odor enhancement, high umami and seafood taste, particularly mussel aroma	Multiple potential applications for products aiming to mimic fishy, crab and mussel taste/odor
Microalgae	 *Nannochoropsis oceanica*	High shrimp aroma	Shrimp
Macroalgae	 *Ulva rígida*	High shrimp aroma	Shrimp but may also be applicable for fish
Macroalgae	 *Saccharina latíssima*	High shrimp aroma	Primarily plant-based shrimp but may also be applicable for fish

Microalgae:
Rhodomonas salina

SUMMARY

Source

Freeze-dried sample from HZ University of Applied Sciences (Vlissingen, Netherlands).

Main function in plant-based seafood

Flavor enhancement - high umami and seafood taste, particularly crab, fish and mussel aroma.

Potential applications

Plant-based crab, fish, and mussel.

Key Findings

Compared to other microalgae and commercially available seaweeds, *Rhodomonas salina* presented the **strongest crab odor score** and a low presence of **floral**, **rancid**, **grassy**, and **earthy odors**. In addition, *R. salina* exhibited **a higher mussel and crab taste**, indicating its potential for use in plant-based crab products.

Academic publication

Potential of microalgae as flavoring agents for plant-based seafood alternatives (2022)

Study Overview

The study compared the taste and aroma of eight different phototrophic microalgae species with five seaweeds to determine their potential as flavor ingredients in plant-based seafood alternatives.

Microalgae:
Rhodomonas salina

Key Compounds for Seafood Flavor

The seafood odor in R. salina is attributed to the presence of odor-active compounds such as dimethyl sulfide (DMS), trimethylamine (TMA), saturated aldehydes pentanal, hexanal, heptanal, octanal, decanal, unsaturated aldehydes 4-heptenal (Z), 2,6-nonadienal (E,E), unsaturated alcohol, 1-octen-3-ol and unsaturated ketone 3,5-octadien-2-one, in the same range that exists in seafood flavorings.

Also, the profile of free amino acids and nucleotides of R. salina is similar to those of the shellfish as their profiles are both dominated by glutamic acid (Glu), alanine (Ala) and arginine (Arg), which could explain the fishy/crab taste of this microalgae.

Disadvantages

- Higher grassy odor compared to seaweeds due to hexanal and heptanal
- Higher bitter taste compared to some seaweed species due to oxidized free fatty acids
- Absence of glycine (Gly), an important amino acid for the sweet taste of shellfish

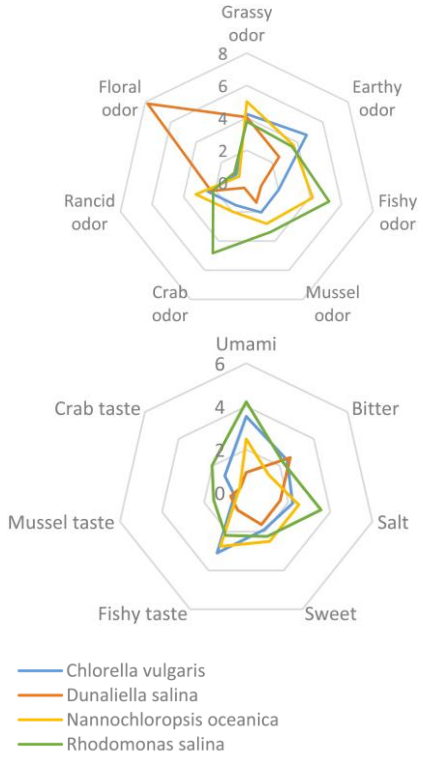

Figure. Sensory data of the study showing that *R. salina* contributes the most fishy and crab aroma compared to other microalgae tested.

Figure. Sensory data of the study showing that *R. salina* has the most umami and salty taste out of all the microalgae tested.

Microalgae:
Rhodomonas salina

Commercial Product Examples

Although still in the experimental phase, Rhodomonas salina is yet to be utilized for commercial seafood products. Nonetheless, ValgOrize has provided a recipe for a mayonnaise that incorporates *R. salina* as an ingredient [1].

In the Landless Food project (Flanders Research Institute) researchers aimed to make microalgae more palatable by growing *R. salina* (and two other species) on edible agar jelly. After two weeks, the algae can be harvested and consumed fresh, potentially serving as a starting point for the development of plant-based seafood products that feature R. salina, known for its strong crab flavor [1, 2].

Figure. *Rhodomonas salina* [3].

ILVO
Flanders Research Institute for Agriculture, Fisheries and Food

Figure. Flanders Research Institute is actively involved in research projects around plant-based seafood, particularly in the areas of algae.

References
1. https://www.valgorize.eu/en/seaweed-passport/rhodomonas
2. https://www.studiomalu.com/landlessfood
3. https://www.sciencephoto.com/media/798007/view/rhodomonas-salina-sem

Microalgae:
Tetraselmis chui

SUMMARY

Source

Frozen paste / freeze-dried powder from Necton S.A. (Olhão, Portugal)

Powder from AllMicroAlgae (Portugal)

Main function in plant-based seafood

Flavor enhancement - high fishy and umami taste as well as crab and mussel aroma

Potential applications

Plant-based prawn and mussel.

Key Findings

Tetraselmis chui **presented seafood odor attributes** such as **fishy**, **mussel** and **crab**, as well as an umami taste. One key advantage of *T. chui* is the **lower bitter scores** compared to other species in the study. Therefore, this species has a great **potential** to be used in **plant-based prawn** and **mussel**.

Academic publication

1. Potential of microalgae as flavoring agents for plant-based seafood alternatives (2022)
2. Active aroma compounds assessment of processed and non-processed micro- and macroalgae by solid-phase microextraction and gas chromatography/mass spectrometry targeting seafood analogs (2022)

Study Overview

Study 1: *T. chui* is compared against the taste and aroma of eight other different phototrophic microalgae species and five seaweeds to determine its potential as flavor ingredient in plant-based seafood alternatives.

Study 2: *T. chui* is compared to the aroma of four algae species (two microalgae and two macroalgae) and investigated their potential to mimic shrimp aroma.

Microalgae:
Tetraselmis chui

Key Compounds for Seafood Flavor:

The seafood odor of *T. chui* can be due to the presence of essential seafood aroma compounds in its composition, such as dimethyl sulfide (DMS), trimethylamine (TMA) and lipid-derived poly-unsaturated aldehydes, alcohols and ketones, which are present in the same range as in seafood flavorings. Also, the profile of free amino acids and nucleotides of *T. chui* is similar to that of shellfish as its profile is dominated by glutamic acid (Glu), alanine (Ala) and arginine (Arg), which could explain the fishy taste of this microalga.

Disadvantages:

- Higher grassy odor ($p < 0.05$) compared to seaweeds;
- Absence of glycine (Gly), an important amino acid for the sweet taste of shellfish.

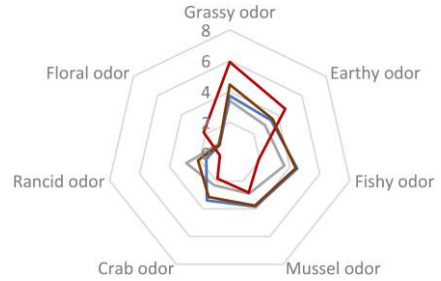

Figure. Sensory data of the study showing that *T. chui* and *P. tricornutum* contribute the most fishy, crab and mussel aroma compared to other microalgae tested.

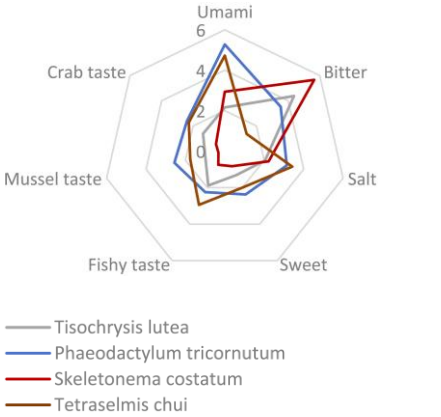

Figure. Sensory data of the study showing that *T. chui* has the most fishy taste out of all the microalgae tested.

Microalgae:
Tetraselmis chui

Commercial Product Examples

No algae-based seafood products with this species have been identified in the market so far, probably because it is in the early stage of development/research.

However, in a Flanders Research Institute project [1], researchers are investigating how to make microalgae palatable by growing Tetraselmis chui (and two other species) on edible agar jelly (a gelatinous product). After two weeks, the algae can be harvested and consumed fresh. This can be a starting point for the production of plant-based seafood containing *T. chui* [2], which is known to have a mixture of prawn and mussel flavours.

Figure. *Tetraselmis chui* [3].

References
1. https://www.studiomalu.com/landlessfood
2. https://www.allmicroalgae.com/en/microalgae/
3. https://www.ccap.ac.uk/catalogue/strain-8-6

Microalgae: *Phaeodactylum tricornutum*

SUMMARY

Source

Frozen paste / freeze-dried powder from Necton S.A. (Olhão, Portugal)

Main function in plant-based seafood

Flavor enhancement - high umami and seafood taste, particularly mussel aroma.

Potential applications

Multiple potential applications for products aiming to mimic fishy, crab and mussel taste/odor.

Key Findings

Compared to some commercial seaweeds (*Palmaria palmata* and *Undaria pinnatifida*), this species displayed **strong seafood odors**, particularly **mussel odor**. It also had the **highest umami** score among the microalgae evaluated, which is significant for the perception of seafood taste. In addition to umami, it had notes of **fishy**, **crab**, and **mussel taste**.

Academic publication

Potential of microalgae as flavoring agents for plant-based seafood alternatives (2022)

Study Overview

The study compared the taste and aroma of eight different phototrophic microalgae species with five seaweeds to determine their potential as flavor ingredients in plant-based seafood alternatives, with commercial seafood flavoring products as a reference. Sensory evaluation and chemical odor-active and taste-active profiles were compared.

Microalgae:
Phaeodactylum tricornutum

Key Compounds for Seafood Flavor:

The seafood odor is due to the presence of odor-active compounds dimethyl sulfide (DMS), trimethylamine (TMA) and lipid-derived poly-unsaturated aldehydes, alcohols and ketones, which are in the same range as those found in seafood flavorings.

Also, the fishy/crab taste of these microalgae is due to the presence of free amino acids and nucleotides in similar amounts to those of the shellfish in terms of glutamic acid (Glu), alanine (Ala) and arginine (Arg).

Disadvantages:

- Higher grassy odor ($p < 0.05$) compared to seaweeds;
- Absence of glycine (Gly), an important amino acid for the sweet taste of shellfish.

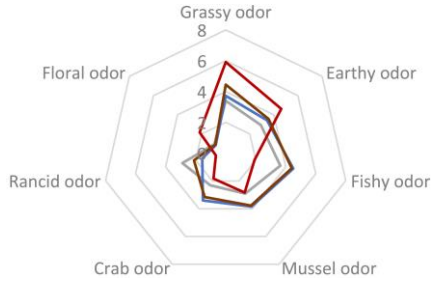

Figure. Sensory data of the study showing that *T. chui* and *P. tricornutum* contribute the most fishy, crab and mussel aroma compared to other microalgae.

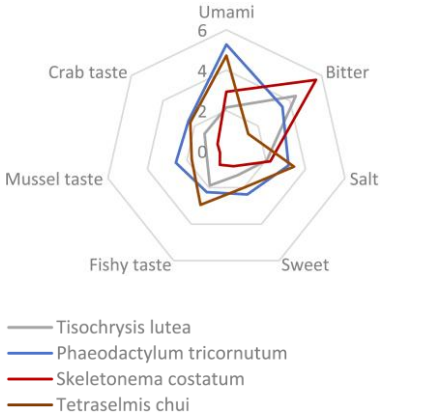

Figure. Taste evaluation results of the study showing that *P. tricornutum* has the most mussel and umami taste compared to other microalgae.

Microalgae:
Phaeodactylum tricornutum

Commercial Product Examples

While there are currently no commercially available seafood alternatives that utilize *P. tricornutum*, the potential for this microalga as an ingredient in plant-based seafood cannot be overlooked. Its high nutritional value and ability to mimic the taste and texture of seafood make it a promising candidate for future product development. Therefore, the absence of *P. tricornutum* in existing seafood alternatives indicates an untapped opportunity for the industry to explore this ingredient and its potential benefits.

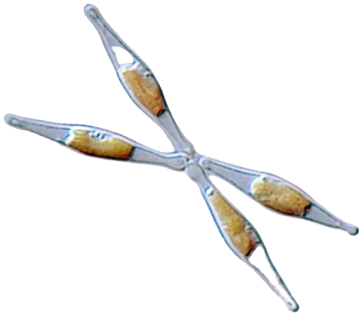

Figure. *Phaeodactylum tricornutum* [1].

References
1. https://en.wikipedia.org/wiki/Phaeodactylum_tricornutum#/media/File:Phaeodactylum_tricornutum.png

Microalgae: *Nannochoropsis oceanica*

SUMMARY

Source

Powder from AllMicroAlgae (Portugal)

Main function in plant-based seafood

Flavor enhancement - high shrimp aroma.

Potential applications

Plant-based shrimp.

Key Findings

This species contains several aroma-active ingredients, or odorants, that are similar in composition to those found in **shrimp**. Promising results were observed in the **raw form (powder)** of the microalgae, but also in the **cooked sample** (solid phase) and **cooking water** (liquid phase), probably due to the presence of key components of odorants (ketones, aldehydes, and alcohols) in all the forms.

The cooking water, which is a **byproduct**, has the potential to enhance the flavor of plant-based seafood products and could be a sustainable and **cost-effective** solution.

Academic publication

Active aroma compounds assessment of processed and non-processed micro- and macroalgae by solid-phase microextraction and gas chromatography/mass spectrometry targeting seafood analogs (2022)

Study Overview

The study compared the aroma of four algae species (two microalgae and two macroalgae) and investigated their potential to mimic shrimp aroma. Sensory analysis and quantification of volatile organic compounds were assessed in non-processed raw samples, and processed cooked and cooking water samples.

Microalgae:
Nannochoropsis oceanica

Key Compounds for Seafood Flavor

The seafood (shrimp) aroma of this species is attributed to the presence of aldehydes (hexanal, 2-octenal, benzaldehyde, 2,4-decadienal, octanal, trans-2-cis-6-nonadienal, and nonanal) as well as the ketone 3,5-octadien-2-one.

Disadvantages

- Despite the detection of aroma-active compounds in this species through chemical analysis, the sensorial evaluation of its potential to mimic shrimp aroma yielded less promising results, possibly due to the intense smell of microalgae compared to shrimp and the expected softer odors.
- To improve the similarity to shrimp aroma, further studies using diluted samples of the algae may be necessary.

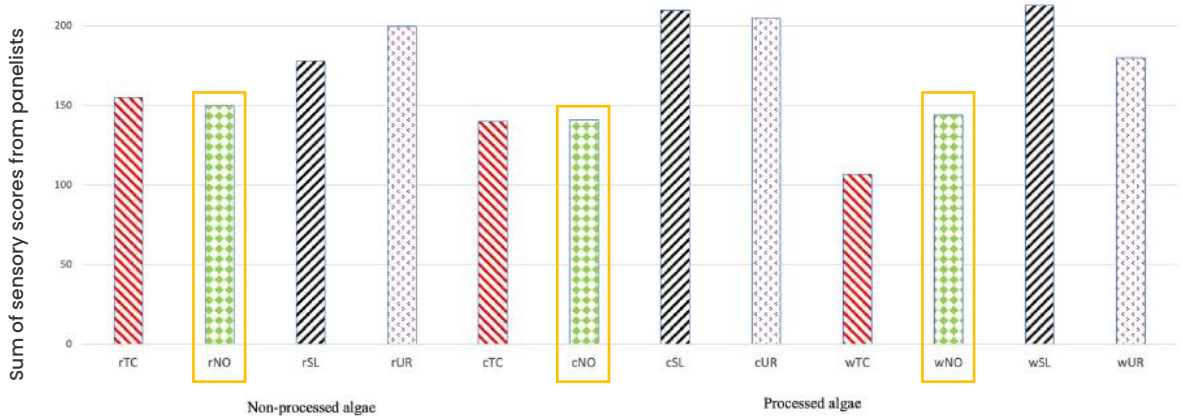

Figure. Sensory data (evaluation sum of panelists' scores) of the study showing that *N. oceanica* presented intermediate scores for shrimp aroma compared to other microalgae tested, in raw form (rNO), cooked sample (cNO) and cooking water (wNO). The greater the score, the more similar it is to the aroma of shrimp.

Microalgae:
Nannochoropsis oceanica

Commercial Product Examples

No commercial products of seafood alternatives containing *N. oceanica* have been found so far.

However, a daily tonic (Nannotine PH Balance) composed by *N. oceanica* is already available in the market as a good non-animal source of omega-3 and protein [1].

While *N. oceanica* has yet to be widely utilized in commercial seafood alternatives, this microalga shows great potential as a key ingredient in the development of plant-based seafood products. With its high protein and nutrient content, as well as its ability to mimic the flavor and texture of seafood, *N. oceanica* presents an untapped opportunity for the industry to create innovative and sustainable plant-based seafood alternatives.

Figure. Nannotine PH Balance, a commercial product containing *N. oceanica* [1].

Figure. *Nannochoropsis oceanica* [2].

References

1. https://www.oceanpureaustralia.com.au/product/nannotine-ph-balance/
2. https://www.ogtr.gov.au/sites/default/files/files/2021-07/the_biology_of_nannochloropsis_oceanica_a_microalga.pdf

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EXPERT INSIGHT

> We should look into more ways of incorporating algae in our product developments. Seaweeds like nori and kombu have a nice ocean flavor and can be used for flavoring. Microalgae is good for nutritional purposes (e.g., proteins and omegas). There's still a lot to be done to unlock their full potential.

Ida Speyer

Co-founder and CEO,
Mimic Seafood

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Microalgae:
Ulva rígida

SUMMARY

Source

Powder from AlgaPlus (Portugal)

Main function in plant-based seafood

Flavor enhancement - high shrimp aroma.

Potential applications

Primarily plant-based shrimp but may also be applicable for fish.

Key Findings

This algae can be a valuable addition to enhance the aroma of new plant-based seafood alternatives, owing to its characteristic **shrimp-like aroma**. **Promising results** were obtained not only with raw algae but also with **processed forms**, such as **solid cooked samples** or **cooking water**.

However, further R&D efforts are required to explore the full potential of this macroalgae in various forms for plant-based products.

Academic publication

Active aroma compounds assessment of processed and non-processed micro- and macroalgae by solid-phase microextraction and gas chromatography/mass spectrometry targeting seafood analogs (2022)

Study Overview

The study compared the aroma of four algae species (two microalgae and two macroalgae) and investigated their potential to mimic shrimp aroma. Sensory analysis and quantification of volatile organic compounds were assessed in non-processed raw samples, and processed cooked and cooking water samples.

Microalgae:
Ulva rígida

Key Compounds for Seafood Flavor

The powder biomass underwent a cooking process in a water bath at 98ºC for 5 minutes, resulting in a solid phase (i.e. cooked sample). The by-product, which is the liquid phase (i.e. cooking water), was also studied. The findings indicated that all products, including the raw biomass, cooked sample, and cooking water, exhibited similarities in shrimp odor. This characteristic was primarily attributed to the presence of **nonanal**, **terpenes**, and **2-octenal**.

Branched-chain alcohols (such as 2-octenal) are associated with **fishy** and **grassy aromas** and seem to contribute significantly to the aromatic profile of this macroalgae.

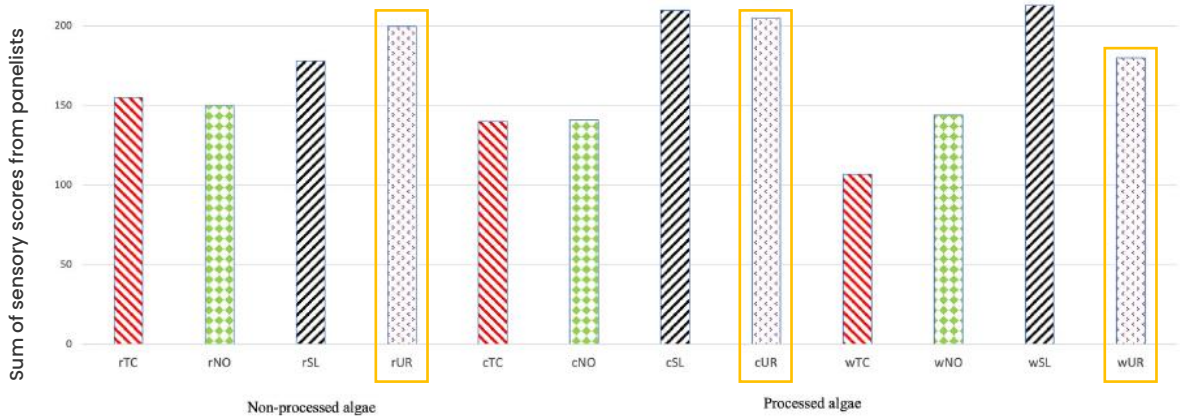

Figure. Sensory data (evaluation sum of panelists' scores) of the study showing that *U. rígida* presented the highest scores for shrimp aroma compared to other microalgae tested in the raw form (rUR), as well as good scores in the cooked samples (cUR) and cooking water (wUR). The greater the score, the more similar it is to the aroma of shrimp.

Microalgae:
Ulva rígida

Commercial Product Examples

While there is currently no widespread use of *Ulva rígida* in commercial plant-based seafood products, this macroalgae species possesses several attributes that make it a promising candidate for use in such products. Its high protein and nutrient content, along with its ability to mimic the taste and texture of seafood, are potential advantages that could be leveraged in future product development. Notably, while *Ulva rígida* has not yet been featured in any commercial plant-based seafood products, it's worth mentioning that a plant-based mushroom snow crab made with seaweed is already available in the market, demonstrating the potential for other seaweed species, including *Ulva rígida*, to be utilized in innovative ways to create sustainable and ethical seafood alternatives [1].

Figure. Plant-Based Seafood Enoki Mushroom Snow Crab containing macroalgae [1].

Figure. *Ulva rígida* [2].

References
1. https://naturamarket.ca/seed-to-surf-plant-based-seafood-enoki-mushroom-snow-crab-95g.html?gclid=CjwKCAiAr4GgBhBFEiwAgwORrWvcOL_1zQ_mILdHrsMpiQmPucT_jFWW7K1ZoiNML10YMmTGTvXZfxoCnVUQAvD_BwE
2. https://www.algaplus.pt/especies-em-cultivo/ulva-rigida/

Microalgae:
Saccharina latíssima

SUMMARY

Source

Powder from AlgaPlus (Portugal)

Main function in plant-based seafood

Flavor enhancement - high shrimp aroma.

Potential applications

Primarily plant-based shrimp but may also be applicable for fish.

Key Findings

S. latíssima showed the **best similarity to shrimp aroma** compared to two other microalgae and one macroalgae when tested as **cooked samples** and **cooking water**. It also demonstrated the **second best** match for shrimp aroma (among the other algae) when tested in its **raw form**.

These promising aroma results indicate that this algae has potential for use in enhancing the aroma of new plant-based seafood products. Further research and development could explore various applications of this macroalgae in plant-based products, as it has exhibited good performance in multiple forms.

Academic publication

Active aroma compounds assessment of processed and non-processed micro- and macroalgae by solid-phase microextraction and gas chromatography/mass spectrometry targeting seafood analogs (2022)

Study Overview

The study compared the aroma of four algae species (two microalgae and two macroalgae) and investigated their potential to mimic shrimp aroma. Sensory analysis and quantification of volatile organic compounds were assessed in non-processed raw samples, and processed cooked and cooking water samples.

Microalgae:
Saccharina latíssima

Key Compounds for Seafood Flavor

The powder biomass underwent a cooking process in a water bath at 98°C for 5 min, resulting in a solid phase (cooked sample), and the liquid phase (cooking water) was also examined.

Results showed that **all the products** (raw biomass, cooked sample and cooking water) had **similarities with shrimp odor**, which was attributed mainly to the presence of **nonanal**, **terpenes**, and **2-octenal**. **Branched-chain alcohols (such as 2-octenal)** are **associated with fishy and grassy aromas** and seem to contribute significantly to the aromatic profile of this macroalgae.

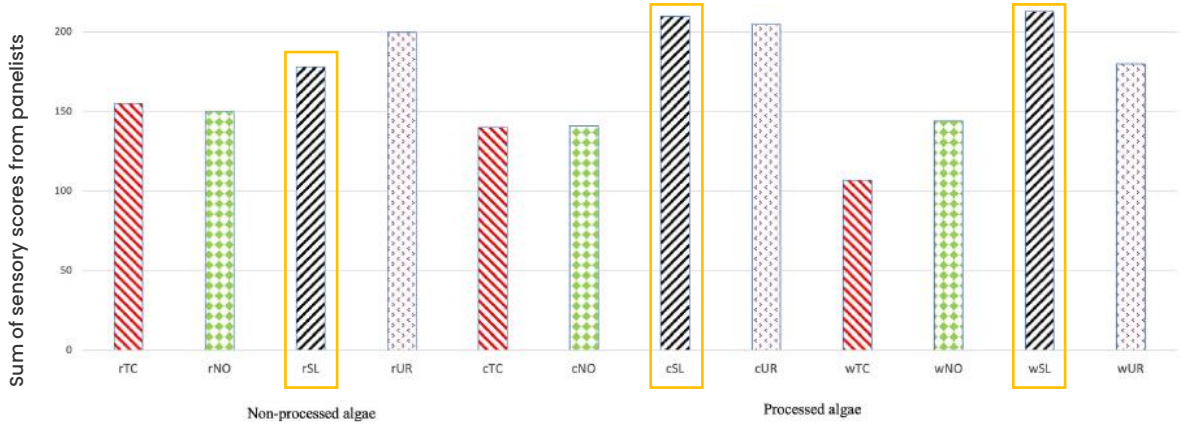

Figure. Sensory data (evaluation sum of panelists' scores) of the study showing that *S. latíssima* presented the highest scores for shrimp aroma compared to other microalgae tested in the cooked samples (cSL) and cooking water (wSL) form, and the second better score in the raw form (rSL). The greater the score, the more similar it is to the aroma of shrimp.

Microalgae:
Saccharina latíssima

Commercial Product Examples

Although no specific examples of application of this species of algae were identified, as mentioned previously, a plant-based mushroom snow crab, made with seaweed, is already available in the market [1].

While there is currently no widespread use of this brown macroalgae species in commercial products, the success of seaweed-based products such as the mushroom snow crab demonstrates the untapped potential of *Saccharina latíssima* and other seaweed species in the plant-based seafood industry.

Figure. *Saccharina latíssima* [2].

References

1. https://naturamarket.ca/seed-to-surf-plant-based-seafood-enoki-mushroom-snow-crab-95g.html?gclid=CjwKCAiAr4GgBhBFEiwAgwORrWvcOL_1zQ_mILdHrsMpiQmPucT_jFWW7K1ZoiNML10YMmTGTvXZfxoCnVUQAvD_BwE
2. https://www.centralcoastbiodiversity.org/sugar-kelp-bull-saccharina-latissima.html

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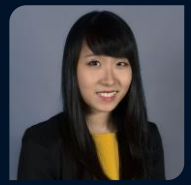
Gareth has been with PreScouter since 2015, and specializes in the Food & Beverage and Life Sciences industries. Since joining the PreScouter team, he has worked across multiple topics ranging from product and process improvement and development, and sustainability throughout the food and beverage industry as well as healthcare. Gareth's research background at the University of Alberta is in the biochemistry of membrane proteins in health and disease. Prior to joining the PreScouter team, he was a project coordinator for the Cancer Research Institute of Northern Alberta (CRINA).



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