Submission for public consultation - Towards a strong and sustainable EU algae sector

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Introduction and overview to this document

The Good Food Institute welcomes the opportunity to provide feedback on the proposed EU Algae Initiative.

We wholeheartedly agree with the Commission's assessment that algae represent a largely untapped resource that can be utilised to relieve the pressure and demands on wild fish stocks and coastal ecosystems. We also welcome the recognition that algae are an important source for alternative protein.

Similarly, we applaud that the Commission has separately identified that cultivated seafood (cellular mariculture) offers "an innovative method of reconciling the increasing global demand for protein with the various health, environmental, economic, and ethical issues linked with animal farming industries."[1]

As an international non-governmental organisation that works to advance plant-based, fermentation-derived, and cultivated (grown from cells) seafood, we have a number of concrete recommendations for how the EU's Algae Initiative can leverage the potential of seafood and microalgae to make further progress in aligning Europe's food supply with the goals set out in the European Green Deal.

The recommendations of this briefing document are focussed on the regulatory, research and infrastructure priorities we have identified within the scope of Option 2, Points 2 and 5 as identified in the Roadmap document: "Supporting the functioning of the market" and "Closing knowledge, research and innovation gaps."

[1] Blue Bioeconomy Report, December 2020, page 102.

Given the reference to cellular mariculture as a topic of interest in both this document and in the Commission's Blue Economy Communication, we are also taking the opportunity to present our main recommendations about the priorities for advancing the European cultivated seafood space.

Why alternative seafood

The alternative seafood industry —plant-based, cultivated, and fermentation-derived fish and shellfish — is one promising solution to the emerging growing demand for seafood both in Europe and around the world. Both macroalgae and microalgae have enormous potential as ingredients and enablers for sustainable alternative seafood production.

Demand for fish and shellfish is growing globally with the global population expected to reach nearly 10 billion people by 2050 and per capita fish consumption doubling between 1960 and 2013. In Europe, more than half—about 55 percent—of seafood demand is met by foreign supply. With catches from wild fisheries on the decline and aquaculture not projected to keep pace with demand, Europe urgently needs a new and sustainable domestic seafood industry.

The development and widespread commercialization of plant-based seafood (using plant-derived ingredients to replicate the flavor and texture of seafood), fermentation-derived (using traditional, biomass, and precision fermentation to create products indistinguishable from conventional fish and shellfish), and cultivated seafood (produced by cultivating cells from marine animals) is an immensely promising approach for alleviating pressure on both wild fisheries and aquaculture systems if pursued in coordination with the right enabling policy frameworks. Plant-based, fermentation-derived, and cultivated seafood exhibit fundamentally higher efficiencies than cycling caloric value through animals, and they offer the unique opportunity to level the trophic playing field within seafood production. In other words, the raw materials and resources to create plant-based, fermentation-derived, or cultivated versions of a top predator like tuna are essentially the same as those required for those new versions of species at the bottom of the food chain.

Accelerating the development and commercialization of scalable plant-based, fermentation-derived, and cultivated seafood products that compete on taste, price, accessibility, and nutritional quality with their ocean-derived counterparts should comprise a core component of European strategies to maintain the vitality and, ultimately, the survival of our oceans. In the last decade, the global market has seen massive shifts in consumer demand and product innovation for plant-based alternatives to products of terrestrial animal agriculture. The European plant-based meat and dairy sectors have experienced double digit growth year on year over the last decade, and growth is expected to nearly double again over the next five years.[2] These trends are likely to reflect a similar forthcoming transformation within the seafood industry. In fact, there is reason to believe that the transition of seafood toward plant-based and cultivated meat solutions will occur with more urgency than for products like meat, poultry, and dairy, for which production has largely kept pace with increasing demand. The rapidly growing unmet demand for seafood coupled with the looming collapse of many global fisheries is likely to accelerate this shift.

The case for public R&D funding

While alternative seafood products will ultimately be produced and supplied through the private sector, the underlying technologies and their path toward commercialisation will require a robust innovation ecosystem. Given that very little funding outside of a few companies' R&D budgets has been expended in this area and that the estimated total global R&D expenditure to date across all forms of plant-based, fermentation-derived and cultivated seafood is on the order of about €85 million, this industry exhibits tremendous potential to benefit from concerted public and private resource allocation.

Public investment fills a very different role than private sector investment. Unlike companies, which have an incentive to protect their research and innovation and seek individual return on investments, public funds can be invested into answering long-term, forward-looking R&D questions that can accelerate entire industries. As has already happened in the field of renewable energy, governments can play a unique role by prioritising open-access R&D funding that ensures the benefits are democratised, further catalysing innovation across the whole sector.

To accelerate the process from early product development through to widespread market adoption across Europe, coordinated policy must be pursued to support the essential foundation research underlying the sector. Specifically, the European Commission should:

1. Develop an **alternative seafood strategy** with an action plan setting out how to advance the industry (in conjunction with all relevant

[2] ING, Growth of plant-based meat and dairy is stirring up the European food industry, October 2020.

Directorates-General, such as DG RTD and DG GROW).

2. **Embed alternative seafood** at the heart of the 'Healthy oceans, seas, coastal and inland waters' mission area and specifically as a key contributor to the goal of regenerating marine and freshwater ecosystems. At least **10% of R&D funds** within this mission should be made eligible for research advancing alternative seafood.
3. Open **dedicated call proposals for open-access research into alternative seafood** under Horizon Europe Cluster 6 and under the European Maritime Fisheries and Aquaculture Fund, ensuring parity of funding with conventional seafood.

How seaweed and microalgae can enhance alternative seafood

Alternative seafood will be successful if products match their conventional counterparts on taste, price, and convenience, the three primary drivers of consumer food choice. For fish and shellfish, a key to unlocking the potential of plant-based, fermentation-derived, and cultivated seafood is the use of algal ingredients, both macroalgae (or seaweed) and microalgae.

Seaweed and microalgae exhibit functional properties essential to matching the sensory profile of fish and shellfish, from serving as binders to giving products their ocean-like aroma. These ingredients can also provide alternative seafood products with the nutritional profile that consumers expect from conventional seafood.

Consumer acceptance is a key hurdle in the effort to unlock the algae sector in Europe. Consumers tend to choose foods that are familiar to them, including alternative protein products. Fishery and aquaculture products in particular are chosen primarily based on appearance. Incorporating algal ingredients into alternative proteins that look, smell, taste, and cook like their conventional counterparts is therefore a promising solution to the potential for low consumer acceptance of algae as a standalone food.

Alternative protein—both alternative seafood and other alternative protein products—serves as a growing market for algal ingredients. Closing knowledge, research, technological and innovation gaps on the application of both macro- and microalgae in alternative protein will enable the sustainable scaleup of the Euoprean's algae industry.

Research needs for seaweed and microalgae for alternative proteins

Below are several key research priorities related to the use of seaweed and microalgae in alternative proteins broadly.

Generating open access data on ingredient functionality, sensory properties, and nutritional value for microalgal and seaweed species

Little information is available on the functionality of ingredients, especially proteins derived from algal species that are, internationally, categorized as generally regarded as safe (GRAS), other than polysaccharides or oils extracted from algae. There is a need to generate more data as applicable to creating alternative protein products. For example, data on water-holding and emulsification capacity is critical to creating plant-based meat and seafood products, while data on solubility is critical to creating plant-based dairy products. In addition, data on organoleptic properties of algae-derived ingredients in terms of color, taste, odor and flavor is essential for their usage in alternative protein products. Nutritional data on protein content, amino acid profiles, bioavailability, bioaccessibility, and bioactivity of proteins from algae should be available for it to ensure products are attractive to both ingredient manufacturers and consumers. Comparisons against common protein sources like soybean, eggs, and dairy should be made to evaluate the potential of algal proteins as an alternative protein source. Such studies could either be conducted by academic researchers or private companies developing alternative protein ingredients and products.

Optimizing the type and format of algae for alternative protein applications

Health benefits associated with seafood consumption are often attributed to the presence of omega-3 fatty acids, high vitamin D and B12 content, and minerals like iron, zinc, iodine, magnesium, and potassium. However, fish obtain these nutritional components from the consumption of marine microalgae. Since European consumers look for not only taste and convenience but also nutritional benefits from a seafood product, algae is a natural choice for sourcing ingredients that enhance the nutritional value of plant-based seafood products.

Some microalgae species are rich sources of beta carotene, astaxanthin, polyunsaturated fatty acids, omega-3 fatty acids, polyphenols, sterols, and antioxidants in addition to minerals like calcium, sodium, magnesium, phosphorus, potassium, zinc, iodine, etc. Seaweeds are also rich sources of micronutrients. Seaweeds are the best natural sources of iodine and of soluble vitamins A, D, E, K, C, B1, B2, B9, B12 and essential minerals like calcium, iron, magnesium, phosphorus, potassium, zinc, copper, manganese, selenium, and fluoride (Mišurcová 2011, Qin 2018).

Seaweed-based products like carrageenan, agar, alginates, and other polysaccharides can also act as structuring agents. Due to the high water holding capacity of seaweed-derived polysaccharides, these can act as gelling agents and binders. Thus, seaweeds can be utilized as sources of texturizing, especially for alternative seafood products. The characteristic umami flavor found in seafood from the presence of certain amino acids like aspartic acid and glutamic acid can be achieved in plant-based seafood products through the incorporation of microalgae and seaweed as ingredients. However, the type, content, and format of microalgae and seaweed used for such purposes need to be explored.

Developing and scaling up of biorefinery to valorize all value-added components from algae

Some of the ingredients accumulated in algae cells, like bioactive and nutraceutical compounds and pigments are of high economic value. Minimal research has been conducted, however, on the potential to valorize side streams including proteins, polysaccharides, and minerals. Algae-derived polysaccharides in particular have already demonstrated value as thickeners and binders in plant-based egg and dairy applications, and certain algal hydrogels have been explored for creating scaffolds for cultivated meat. To reduce the cost of bulk ingredients like proteins for alternative meat, egg, dairy, and seafood, one opportunity would be to establish "algal biorefineries," which would integrate various extraction processes and equipment to commercially produce protein as well as other value-added products from algae. This concept is analogous with petroleum refineries, but a similar model can be extended to algae processing.

Create open access database on toxicity and allergen potential for various algal species

For food applications of microalgae and seaweed-derived proteins, it is critical to evaluate the safety of these materials for human consumption. Data on toxicity and allergen potential needs to be generated to guide decision making on the approval of protein extracts from new species and novel strains. For example, more research is needed to understand the bioaccumulation of toxic metals in seaweed. Creating a readily available database on toxicity and allergen potential will be valuable for both industries as well as regulatory bodies.

Development of scalable protein extraction processes for expressing specific functional properties and organoleptic properties

Processing at each stage of the algae value chain contributes to functional properties exhibited by algal proteins. The protein extraction stage is critical to ensuring the desirable proteins are extracted, which exhibit the desired functional properties like solubility, emulsification, and water holding capacity. Currently, some research exists on protein extraction methods like isoelectric precipitation, and filtration. Still, more research is needed on applying these methods to algae to extract algal proteins, while also optimizing for organoleptic properties.

Research needs specific to cultivated seafood (cellular mariculture)

Below are key research priorities related to the use of seaweed and microalgae in cultivated seafood.

Algae and cultivated seafood

A particular challenge for cultivated seafood (as opposed to cultivated terrestrial meat) is the difficulty of sourcing compounds such as long-chain omega-3 fatty acids and marine-derived carotenoids in sufficient quantities. Because fish and other aquatic animals primarily obtain these compounds from their diet (ultimately from algae, either directly or by consuming other animals), cultivated cells from these organisms are not expected to produce the same fat profile as that found in conventional seafood. This is especially true for marine top predators, which naturally contain high amounts of long-chain omega-3s. This challenge can be addressed by feeding these compounds to the cultivated cells, but a number of research directions still remain to be explored. These include methods for producing and purifying marine-derived compounds at scale by farming algae or by other methods, optimizing the process for adding these compounds to the cells or the product, and understanding the effects of how how the compounds are introduced (e.g. added during cultivation or in a final processing step) on the risk of oxidation or other chemical changes of the final product during storage.

Other algal-derived compounds, such as carrageenan, readily form hydrogels with properties that may be desirable in scaffolds for cultivated meat and seafood. Investigations into the properties of such compounds, determination of the best methods for formulation of scaffolds suitable for structured three-dimensional cell culture, and assessments of the potential environmental footprint and cost-effectiveness of their large-scale use for this application may open doors to improving the cost, scalability, and nutritional and organoleptic properties of both cultivated meat and seafood.

These research endeavors provide multiple opportunities for proactive engagement with the existing seafood industry and other entities that protect fisheries and ocean ecosystems. Obtaining access to high-quality primary tissue may require partnering with marine research or conservation organizations, aquariums, aquaculture facilities, or even industrial or recreational fishers. Collaborations involving aquaculture research institutes may prove particularly valuable because the aquaculture industry is experienced in handling aquatic species at all stages of maturity including embryos, and it routinely uses fish cell culture for advanced breeding and to monitor stocks for pathogens.

OTHER CULTIVATED SEAFOOD RESEARCH PRIORITIES

Cell culture of aquatic species is not prevalent in academic research. There is a substantial need to develop the tools and resources that are already well established for mammalian cell culture — such as cell lines, robust protocols, commercial reagents, transfection vectors and reporters, full genome sequences, and biomolecular ("-omics") datasets for cells derived from aquatic species. These data and research tools would contribute greater mechanistic insights into the metabolism, growth, and developmental cell biology of these species, which may differ from the canonical pathways that are well characterized in mammalian species. Because of the development of less expensive, higher-throughput techniques for performing all of this work, the required investment in terms of funding, effort, and time to develop comprehensive data sets for each aquatic species will be orders of magnitude smaller than historical investment to develop these resources for the mammalian research community.

At present, the difficulty of obtaining such cell lines is a significant barrier to entry for both academic researchers and commercial ventures. Fresh primary cell isolates for terrestrial farmed animals can typically be obtained by partnering with a slaughterhouse, a school of veterinary medicine, or a university animal science department. However, most veterinary medicine and animal science departments do not typically work with aquatic species, and the majority of fish slaughter occurs at the site of harvest rather than at a centralized slaughter facility. Furthermore, it is exceedingly difficult to obtain fresh tissue for exotic species or deep-ocean species, and it can be virtually impossible to obtain embryonic tissue – which is often desirable for high proliferative capacity and its ability to generate all meat-relevant cell types – for species that are not bred in captivity, which suggests that induced pluripotent stem cell lines may be particularly valuable. Protocols for deriving these cell types need to be developed and optimized for aquatic species. Globally, research projects at Mote Marine Laboratory and Tufts University aim to develop novel cell lines from species commonly consumed as seafood.

Development of open-source optimized culture media formulations for growth of aquatic cells is another area with great potential to both benefit the growing cultivated seafood industry as well as to enable further academic research into methods for cultivating seafood. Finfish cells will generally grow in media formulations similar to those used for cells from other lineages, but further research is needed in order to remove FBS and other animal-derived components without sacrificing performance, optimize formulations for specific species or cell lines, and ensure optimal nutrition profiles in the final product. Ongoing research at Virginia Tech aims to address this problem by using machine learning to optimize media for growth of finfish cells.

Regulatory Priorities

In addition to the research priorities laid out above, the following steps should be taken to establish a regulatory framework for cultivated seafood in the European Union.

1. **Create specific guidance documents** on the preparation of a safety dossier for novel plant-based food products that contain algae, foods produced with biomass fermentation and precision fermentation, as well as cell-based seafood.
2. Ensure the regulatory framework includes **a mechanism for amending dossiers during review and after acceptance**. This is important in light of the dynamic nature of product development in the rapidly changing alternative protein sectors.