Unlocking the potential of macroalgae for a thriving European blue bioeconomy

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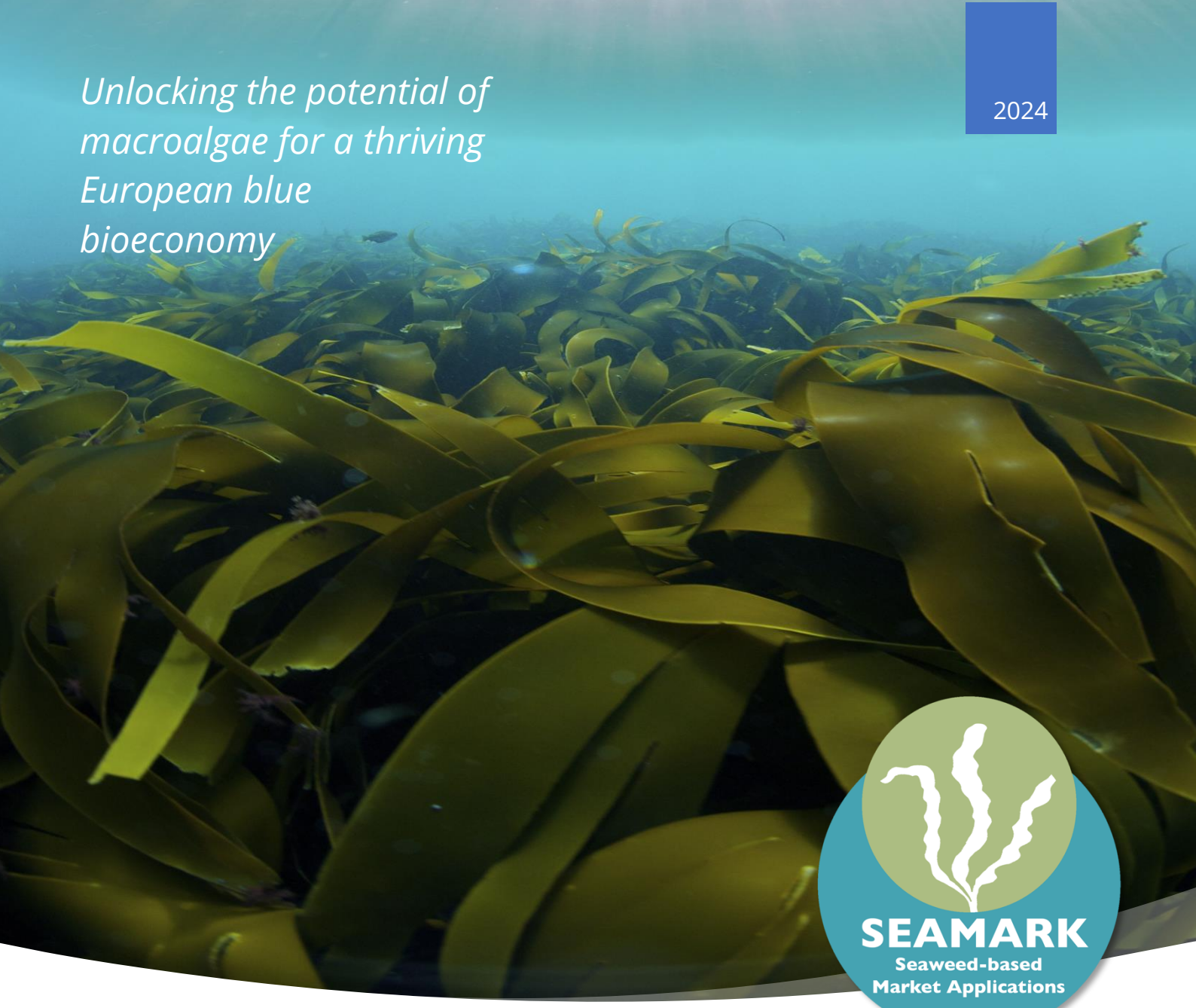

SEAMARK
Seaweed-based Market Applications

Initial assessment of market potential

SEAMARK DELIVERABLE 7.3

NOFIMA

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SEAMARK DELIVERABLE 7.3: INITIAL ASSESSMENT OF MARKET POTENTIAL

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Abstract

The main objective of the SeaMark project is to demonstrate how to scale up innovative seaweed cultivation and processing into price-competitive product applications making the entire supply chain attractive for commercial investments. This report is the third outcome from SeaMark Work Package 7 (WP7) – Go-To-Market (GTM) strategies for products, and it builds a foundation for the contribution of WP7 to the SeaMark objective "Analysis of markets and consumer preferences" (Specific Objective 9).

WP7 deals both with the SeaMark flagship products and the SeaMark innovation products. For the flagship products, GTM strategies and SWOT (Strengths, Weaknesses, Opportunities, Threats) analyses were outlined in D7.1. The first part of this report contains similar analyses for the SeaMark innovation products which are:

- Bioactive fucoidan, Oceanium, United Kingdom
- Bio-packaging materials, Oceanium, United Kingdom
- Meat replacer product, Fermentationexperts, Denmark
- Designer alginates, Algaia, France
- Fucoidan extraction with enzymes, Algaia, France

The initial analysis of GTM strategy is based on semi-structured expert interviews with key commercial stakeholders (Oceanium, Fermentationexperts and Algaia) based on a common interview guide agreed in advance. A SWOT analysis was then carried out to outline the opportunities and constraints of various GTM strategies.

The second part of this report expands on this preliminary analysis of GTM strategies both for the SeaMark flagship products (D7.1) and for the innovation products (first part of this report) and performs an initial assessment of their market application potential. This assessment is based on additional interviews with the stakeholders to get an update about the Technological Readiness Level (TRL) and Unique Selling Points (USPs) for the products. Further, in-depth interviews have been conducted with the industry purchasing group (IPG) and other potential buyers within the nutraceutical, cosmetic, pig feed, and alginate markets to conduct the initial assessment of market potential.

Three production scenarios have been selected, focusing on the feasibility of rapid prototyping (short-term production scenarios) of the SeaMark products. The assessment shows that the SeaMark fucoidan products (bioactive fucoidan and fucoidan extracts with enzymes) for the cosmetic market, bioactive fucoidan for nutraceuticals, bioactive beta-glucans for cosmetics, and green alginates for food texture are the most promising short-term scenarios and are thus selected for the feasibility study (D7.4).

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LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
CAGR	Compound Annual Growth Rate
CSF	Critical Success Factor
DSHEA	Dietary Supplement Health and Education Act
EFSA	European Food Safety Authority
GDPR	General Data Protection Regulation
GMP	Good Manufacturing Practice
GRAS	Generally Recognized As Safe
GTM	Go-To-Market
HACCP	Hazard Analysis and Critical Control Points
INCI	International Nomenclature Cosmetic Ingredient
IPG	Industry Purchasing Group, SeaMark stakeholder group
LCA	Life Cycle Assessment
SWOT	Strengths, Weaknesses, Opportunities, Threats
TRL	Technological Readiness Level
USP	Unique Selling Point
WP	Work Package

CONTENTS

INTRODUCTION

Background

Seaweed cultivation is a highly efficient way to produce nutritious food and other important products in a sustainable way. Unlike terrestrial crops, seaweed does not require fertilizer, fresh water, or land use to be cultivated. It acts as an underwater habitat for a diversity of marine life, and it absorbs carbon, nitrogen, and phosphorus. Seaweed has a lot of bioactive ingredients, can be used in both human and animal foods, and can be found in a variety of other products like nutraceuticals, cosmetics, and packaging materials. SeaMark will demonstrate how to scale up innovative seaweed cultivation and processing into price competitive product applications making the entire supply chain attractive for commercial investments.

To be competitive, companies need to develop new products to meet consumers' ever-changing needs and wants. Product development is especially important for the cultivation of seaweed in Europe as this can provide new valorisation opportunities and help develop this new industry Many of the potential applications of seaweed are currently being explored and require further research and investment before the potential can be ascertained. The key challenge with new product development is achieving success. A common belief is that 80% of new products fail (Castellion and Markham 2013), however recent studies suggest that this rate may be as low as 25% (Victory *et al.,* 2021). Regardless of the failure rate, the literature agrees with the fact that new product development is risky. One way of reducing this risk is to combine new product development efforts with good business models and go-to market (GTM) strategies (Kuester *et al.,* 2018). In WP7 one of the main goals is to develop GTM strategies that can serve as a basis for successful production, sales, and delivery of selected SeaMark products.

A GTM strategy is a comprehensive plan created by an organization to successfully launch a product or service to market. A GTM strategy generally includes the following elements:

- Product description
- Product strengths
- Product-market fit
- Target market
- Competition and demand
- Distribution
- Price

While each product and market will be different, a GTM strategy should identify a market problem and position the product as a solution. To assess the different GTM strategies a SWOT analysis is used. The intention of the SWOT analysis is to identify the internal strengths and external opportunities that a company can utilize to accomplish its objectives, while also pursuing the alleviation of internal weaknesses and external threats (Lewis and Littler, 1997). The external analysis of the GTM strategies focuses on the environmental threats and opportunities facing the companies, while the internal analysis helps identify product and organizational strengths and weaknesses. It also helps to understand which resources and capabilities are likely to be sources of competitive advantage and which are less likely to be sources of such advantages. Based on the SWOT analysis, the initial GTM strategies of the different companies can be evaluated.

To evaluate the application potential for seaweed products it is important to have knowledge about the market segments in which the products are planned to be sold. To assess the different markets important elements are:

- Market organization
- Degree of competition
- Factors influencing supply and demand
- Opportunities
- Risks
- Buyer preferences
- Potential for differentiation
- Distribution of power
- Variability over time

It is also important to have access to key market informants. In the SeaMark project, this is mainly gained from the consortium and the IPG.

Objective and scope of this deliverable

The main goal of WP7 is to develop GTM strategies for the SeaMark flagship and innovation products. WP7 will identify the most relevant and promising seaweed products, establish a platform for market exploitation and investigate the market structure and potential for these products. SeaMark will demonstrate market applications through sales and deliveries, beginning with pilot-scale quantities and then moving into industrial-scale quantities. Finally, SeaMark will develop and implement a robust and proven GTM strategy for selected products.

The first part of this deliverable is the framing of ideas and in-depth interviews relating to the 5 SeaMark innovation products. An overview of the 5 innovation products can be found in Table 1 (next page).

Table 1: SeaMark innovation products, producer, and origin

Product:	Product name:	Producer:	Origin:
P2	Bioactive fucoidan	Oceanium	United Kingdom
P3	Bio-packaging materials	Oceanium	United Kingdom
P6	Meat replacer product	Fermentation-experts	Denmark
P8	Designer alginates	Algaia	France
P9	Fucoidan extraction with enzymes	Algaia	France

This part of the deliverable supplements D7.1 "Specification of flagship products (Table 2) and plan market strategy" where GTM and market application potential for flagship products is outlined and D8.1 "Characterization of SeaMark Products" where more detail on the flagship and innovation products and the associated processes and supply chains can be found.

Table 2: SeaMark flagship products, producer, and origin

Product:	Product name:	Producer:	Origin:
P1	Bioactive beta-glucans	Oceanium	United Kingdom
P5	Pig feed	Fermentation-experts	Denmark
P7	Green alginates	Algaia	France

This part of the deliverable will outline the initial analysis of the innovation products and opportunities and constraints relating to their GTM strategies. The deliverable is based on feedback from the users (e.g., the partners producing the SeaMark products) obtained through semi-structured interviews. The collated feedback of the initial GTM strategies forms the basis for a SWOT framework for the different customer segments. Findings will serve as input for T7.3 (investigate market structure and potential for algae products), and T7.4 (initial assessment of market application potential) and the industry purchasing group (IPG).

The one common ingredient for the different innovation products is the use of seaweed. The 5 innovation products focus on different customer segments:

- Bioactive fucoidan for nutraceutical and cosmeceutical application.
- Bio-packaging materials for packaging applications.
- Meat replacer product for food.
- Designer alginates for cosmetic texture and medical device.
- Fucoidan extraction with enzymes for feed and cosmetics.

The second part of this report will expand on this preliminary analysis of GTM strategies both for the SeaMark flagship products (D7.1) and for the innovation products (first part of this report) to give an initial qualitative assessment of market application potential, including Critical Success Factors (CSFs) for the SeaMark flagship and innovation products.

Information about the market structure and potential are collected and analysed for both the innovation and flagship products into the markets for nutraceuticals, pig feed, cosmetics, and alginates.

The final part of the report also includes an initial assessment of market application potential (T7.4) which is based on input from T7.1, T7.2, and T7.3. The 3-4 most promising scenarios for rapid prototyping will be selected for a feasibility study. The results are illustrated by a priority matrix (Table 3) and a description of potential is set in promising scenarios from a short-term, medium-term, and long-term perspective.

Target audience

The report serves as input for the seaweed industry in general, and specifically for the SeaMark stakeholders.

Structure of the document

The first part of the document describes the five SeaMark innovation products. It contains the initial analysis of GTM strategies based on expert interviews. Findings are then summarised in a SWOT analysis for each product.

The second part of the document evaluates the market potential of both the flagship and the innovation products, and it is structured by some of the potential market segments; nutraceuticals, cosmetics, pig feed and alginates for both the innovation products and the flagship products listed in *Table 1* and *2*. Within the different segments, we have tried to reveal the:

- Market organization.
- Degree of competition.
- Factors influencing supply and demand.
- Opportunities.
- Risks.
- Buyer preferences.
- Potential for differentiation.
- Distribution of power.
- Variability over time.

In the discussion of these results, the aim is to provide an initial assessment of market application potential (T7.4) by identifying the short-term, medium-term, and long-term production scenarios of the products into the different market segments.

METHODOLOGY

Data collection

The information collected for the initial GTM strategy for the innovation products is based on expert interviews with key personnel amongst the industry partners involved in the processing of the products. The industry partners are Oceanium Ltd, Fermentationexperts AS and Algaia. When feasible, the interviews were conducted at the production site. In other cases, the respondents filled out a survey followed by an online interview. To make the data collection more efficient, the data collection process was coordinated between WP7, WP8 and WP9 with representatives from the different WPs participated in the interviews. The interviews were made based on a semi-structured interview guide/survey (appendix 1) that covered the different elements of a GTM strategy described in the introduction.

The first company was interviewed in person. The CEO and Project Manager attended the interview.
The second and third companies received the interview guide/survey by e-mail. The Business Development Director, Corporate Affairs and Impact Manager, R&D Manager and Corporate Affairs/Marketing Associate attended the follow-up meeting on Teams.

To assess the market potential for algae products for nutraceuticals, pig feed, cosmetics, and alginates, 10 in-depth interviews with the IPG and potential buyers were conducted. Furthermore, interviews with the industry partners and secondary literature were applied. Interview guides were made to structure the interviews (appendix 2), including questions about market organization, degree of competition, supply and demand situation, opportunities, risks, buying criteria/preferences, potential for differentiation, distribution of power, and variability over time. The results of these elements are discussed for each of the market segments. The last element, variability over time, is included in the end-discussion of initial assessment of market potential in the short-term, medium-term, and long-term perspective.

The interviews were conducted through Teams, using recording and transcription functions offered by Teams. To ensure correct GDPR (General Data Protection Regulation) handling, the respondents were sent information about data handling and storage in the project, approved by the Norwegian Agency for Shared Services in Education and Research (www.sikt.no). The respondents gave their consent before the interviews. Transcriptions of the interviews were sent for approval and possible correction to all the respondents after the interviews. The data were further analysed and structured by the researchers at Nofima.

In addition, Nofima and Sjókovin have collated existing relevant market information about the market for algae-based products in the targeted markets: nutraceuticals, pig feed, cosmetics, and alginates.

Limitations

It is important to note that the number of interviews conducted is not sufficient to provide any generalization or solid conclusions. The quality of the information from interviews is to a large degree dependent on the knowledge of the IPG and the SeaMark consortium. To gain more knowledge, respondents outside the consortium and IPG were also interviewed. It is challenging to gain a complete overview of the potential of all the products in the much differing markets, given both the complexity of these and budget restrictions. However, the secondary data and the interviews provide valuable insight into the different market segments and are used for an initial assessment of market potential. The selected scenarios from this assessment will be subject to closer scrutiny through a feasibility study (D7.4) in the SeaMark project.

RESULTS AND DISCUSSION

Initial GTM Strategy for the Innovation Products

This chapter is based on feedback from the users (e.g., the partners producing the SeaMark products) obtained through semi-structured interviews. The respondents answered questions about the description of the innovation products and their initial GTM strategy. The collated feedback of the initial GTM strategies of the different users forms the basis for a SWOT analysis for the different GTM strategies. Note that similar analyses for the flagship products can be found in D7.1.

P2: BIOACTIVE Fucoidan

Product description

Fucoidans are a complex series of sulphated polysaccharides found in the cell walls of brown seaweeds (Vo and Kim, 2013). Bio-active properties of fucoidan, such as antioxidant, anticoagulant, antithrombotic, immunoregulatory, antiviral and anti-inflammatory effects have been reported (Wang *et al.,* 2019), however, large variation is observed depending on the source material (Cumashi *et al.,* 2007).

With some cosmetic products, food, and nutritional supplements containing fucoidans available on the market, there is now regulatory approval in the US and Europe for the use of fucoidans in supplements and cosmetics from selected species (Fitton *et al.,* 2019). Fucoidans from wakame (*Undaria pinnatifida)* and bladderwrack (*Fucus vesiculosus*) already have novel foods and GRAS (Generally Recognised as Safe) approval with the US Food and Drug Administration (FDA), which will accelerate approval of sugar kelp fucoidan.

Oceanium has developed a process for fucoidan extraction from sugar kelp. Frozen or dried seaweed supplied by SeaMark partners Ocean Rainforest and Algolesko is the raw material used for this product. By biorefining the components needed for the product are extracted from the seaweed, separated from the fibre, filtrated, and then dried. The powder will be

packed and delivered in food-grade, air-tight containers to customers. Oceanium has developed a fucoidan product with the brand name OCEAN ACTIVES®.

OCEAN ACTIVES® Fucoidan is a water-soluble powder, applicable across multiple product formats. Examples are nutraceutical applications (health supplements) and cosmeceutical applications (skincare).

For more detail on this product, the processes, and the supply chain, see D8.1 "Characterization of SeaMark Products."

Product strengths

The first stage of building a GTM strategy is to identify the strengths of the product. This is done by analysing which strengths or unique properties the product has compared to other solutions in the marketplace.

Oceanium defines an array of potential health benefits as strengths of the bioactive fucoidan produced from seaweed. As a nutraceutical product fucoidan's claimed key properties are the ability to support gut, immune and cardiometabolic health. An advantage is that fucoidan may represent a comprehensive solution for several health problems instead of targeting only one at a time.

As an ingredient in skin health products, bioactive fucoidan's claimed key properties are skin barrier protection, reduced ageing and redness with potential benefits in the management of skin problems.

A potential strength of both the nutraceutical and cosmeceutical products from Oceanium is that they are working on scientifically substantiating claims for bioactive fucoidan. This is done by conducting *in vitro* and *in vivo* testing studies across a range of applications to strengthen both health and cosmetic claims. Providing scientifically substantiated claims for bioactive fucoidan is also a goal of the SeaMark project and will be important for future market potential. Other important players, such as Marinova, do not have robust portfolios of *in vitro/in vivo* tests that validate health claims.

A key strength of fucoidan is its safety. It has a proven safety record in pharmaceuticals, nutraceuticals, and skincare.

The origin and purity of Oceanium's fucoidan are found to provide a competitive advantage over similar products.

Another potential strength is the sustainable production of the seaweed to make the bioactive fucoidan. Oceanium collaborates closely with Ocean Rainforest and Algolesko to sustainably source only the highest quality seaweeds. Oceanium focuses on farmed seaweed rather than wild harvesting due to the potential negative implications of the latter on the environment. Oceanium's proprietary processing technology enables clean and effective extraction of sought-after ingredients. OCEAN ACTIVES® Fucoidan matches high functionality and purity with responsible sourcing and manufacturing, aligning with sustainability-focused brands and customer priorities.

Oceanium has completed GRAS self-assessment enabling sales in the US and has conducted a gap analysis to understand the required activities to gain novel foods approval in the UK and Europe. Oceanium is also in the process of registering an INCI (International Nomenclature Cosmetic Ingredient) name for fucoidans extracted from sugar kelp for the cosmeceutical market. INCI names are systematic names internationally recognized to identify cosmetic ingredients.

The final strength of Oceanium's bioactive fucoidan is the proprietary biorefinery technology. This is a 45-step process 'trade secret' which extracts maximum value from farmed seaweed to produce a suite of high-quality, in-demand products. Through this biorefinery technology, Oceanium can achieve very high purities of fucoidan.

Product-market fit

An important part of a GTM strategy is defining the product-market fit. This is done by analysing what specific problem(s) the product solves or the degree to which a product satisfies a strong market demand.

Bioactive fucoidan specifically addresses important and growing areas of concern in both health and skincare. The unique biorefinery process and benefits of fucoidan from seaweed uniquely address consumers´ desire for all-natural solutions to these problems.

Target market

The second part of a GTM strategy is to identify who is experiencing the problem your product solves.

For the fucoidan products, Oceanium is targeting the high-end nutraceutical (health/supplements) and cosmeceutical (skincare) businesses focused on sustainability and driven by innovation.

Within nutraceuticals, Oceanium is focused on science-driven and data-backed companies with an interest in bolstering or building out health solutions within the three target areas of gut microbiome, immune, and cardiometabolic support. They have begun speaking to several companies across the US (due to less strict regulations in the US compared to the EU) of which formulation work has begun for a commercial product.

Within cosmeceuticals, Oceanium is focused on high-growth, innovative companies with an interest in naturally derived, and specifically ocean-derived, ingredients. They have begun speaking to several companies across the US and the UK, one of which plans to launch a fucoidan-based product in Q4 2023.

For both markets, the ability and willingness to collaborate on marketing and branding is important and a driving factor for partner selection.

The most important factors influencing whether the target customers decide to purchase bioactive fucoidan are reliability and consistency of supply and validation of health claims.

Competition and demand

Oceanium has identified some competition in the market for fucoidan. Fucoidan is currently sold primarily in Asia, with a couple of smaller companies located elsewhere.

To compete with the Asian markets, Oceanium focuses on farmed vs wild harvested seaweed, due to the possible negative impacts of wild harvest on the environment, as well as scalable supply where wild harvest has stagnated. Oceanium's biorefinery model also allows it to extract maximum value from the seaweed, producing a diverse and versatile product portfolio, rather than limiting it to one and not utilising the biomass to its full potential. Additionally, traditional fucoidan makers have used solvents for extraction; Oceanium's process is based on green chemistry principles.

Another fucoidan producer, Australian-based Marinova which uses water-based extraction, sells their ingredient B2B as well as a branded consumer product through their website, on Amazon, and through a distributor website in the UK. Other important players, such as Marinova, do not have robust portfolios of in vitro/in vivo tests that validate health claims. Marinova is heavily involved in research projects *(in vitro* and *in vivo* tests) to be able to validate health claims in the future. However, Oceanium has initiated testing, firstly with *in vitro* testing on digestive health. Further testing will be very important for future market potential.

Fucoidan has thus far been a relatively unknown product in the US, UK, and EU with a currently small market, though with growing B2B interest. Oceanium is targeting leading actors in the health and supplement businesses and already has a pipeline.

In terms of demand for fucoidan, the markets for gut health, immune, and cardiometabolic products are growing at 10%, 5%, and 20+% respectively according to Oceanium, who believe that while these specific health areas are growing rapidly, there is no turnkey solution, especially for the digestive and cardiometabolic areas. Overall, they anticipate an increase in demand for their product. Oceanium is building health and skincare claims through in vitro and in vivo testing, growing consumer, and company awareness of fucoidan as a product and potential solution through an integrated marketing strategy and is also sharing the overall benefits of seaweed as an ingredient source.

Distribution

Oceanium has identified a distribution channel for fucoidan, selling fucoidan as an ingredient directly to high-end nutraceutical and cosmetics customers and has a plan in place for scaled production and distribution in global markets.

Price

Oceanium has developed a pricing strategy for bioactive fucoidan. They have reviewed market pricing based on market reports, mostly based on fucoidan produced and distributed in Asia and have knowledge about their potential customers' willingness to pay for fucoidan.

P3: Bio-packaging materials

Product description

The properties of seaweed-derived compounds make them promising candidates to produce innovative materials in packaging and textile applications. Alginate, carrageenan, and agar are the most suitable compounds to produce biofilms and bioplastics – packaging materials that are biodegradable and renewable (Lomartire *et al.,* 2022).

Oceanium has demonstrated experimental proof of concept to use a seaweed-based material to make a range of formulations that could be delivered as powdered or pelleted material, inks, and coatings which can be sold to producers of packaging, textiles, and materials for a range of applications. Faroese seaweed farmer Ocean Rainforest will supply seaweed for production.

For more detail on this product, the processes, and the supply chain, see D8.1 "Characterization of SeaMark Products."

Product strengths

The accumulation of petrol-based plastic is of growing concern because of its negative effects on organisms and humans. A unique selling point for Oceanium's seaweed-based materials ingredient and formulation is that they are suitable for an incredibly versatile range of materials which could address numerous markets and offer viable alternatives to fossil-fuel base polymers.

Another strength is Oceanium's proprietary biorefinery technology, a 45-step process 'trade secret' which extracts maximum value from farmed seaweed to produce a suite of high-quality, in-demand products. Oceanium's materials could also be added to other bio-based materials for exciting new composites and deliver beneficial functionality.

Product-market fit

A specific problem this product solves is that it is a sustainable source of bio-degradable or compostable material. Oil-based plastics for all current uses are unsustainable and should be preserved for applications where others are not appropriate.

Potential land-based sources of bio-based materials are susceptible to drought conditions, soil erosion and limited freshwater availability. According to Oceanium, seaweed is a more sustainable biomass that doesn't require the same inputs and could be useful for displacement of resource-intensive products.

Target market

The target market for this product is the packaging industry, textiles and apparel sector, printing, and coating industry. Oceanium has identified specific target markets/customers and has begun the development of a go-to-market strategy for its first materials formulation as well as application development with companies committed to next-generation materials.

Competition and demand

The potential competitors are the incumbent conventional fossil-derived polymer materials, cellulosic materials from terrestrial biomass sources and novel bioplastic polymers from fermentation biotechnology which rely on terrestrial biomass as a carbon source. Products using fossil-fuel-based polymers are very cheap, presenting a challenge for competing bio-based materials like seaweed. However, companies at all price points are beginning to adopt next-generation materials.

Distribution

Oceanium has begun identifying distribution routes for some of its more advanced bio-based materials formulations.

Price

The pricing strategy is currently in development.

P6: Meat replacer product

Product description

The meat replacer product is a fermented mixture of seaweed and a protein such as rapeseed meal, soybean meal, fava beans, and chickpeas. The fermentation is done by lactic acid bacteria. The main use for the fermented product is as an additive that can be used to extend the shelf life of meat products (i.e., minced meat products or sausages) or bread. It can also be used to make a hybrid product which is half meat and half plant-based, or a fully plant-based product, e.g., a meat replacer product. Additionally, the product may be used as an additive in for example pesto and hummus.

To make a fully plant-based hamburger or sausage some fibres and vegan binder must be added, like beans or sunflower meal. This produces a vegan meat replacer with no E-numbers (no natural or artificial additives). To avoid E-numbers, Fermentationexperts produce natural binders themselves, replacing methylcellulose.

The product is produced by the Danish company Fermentationexperts with sugar kelp from the Faroese company Ocean Rainforest or sea lettuce from ALGAplus in Portugal.

For more detail on this product, the processes, and the supply chain, see D8.1 "Characterization of SeaMark Products".

Product strengths

As illustrated in the product description the product has many potential product applications as an additive, making it very versatile. Because the fermentation of the product is done by lactic acid bacteria, there is substantial lactic acid remains in the finished product, potentially giving many benefits. In addition, the metabolites produced from the fermentation process leave a lot of beneficial components in the product. According to Fermentationexperts, the products consist of potential prebiotic fibres, lactic acid bacteria, and bioactive metabolites that have putative antioxidant-, antimicrobial-, and anti-inflammatory effects.

According to Fermentationexperts, the fermentation process preserves the vitamins and minerals in a much better way compared to boiling or cooking the product. Fermenting food products, like seaweed or beans, also greatly decreases the bitterness, so they become more palatable.

The meat replacer product is a clean-label product. Edwards (2013) defines clean label as:
"*free of 'chemicals' additives, having easy-to-understand ingredient lists, and being produced by the use of traditional techniques with limited processing.*"

The clean-label market trend has also been mentioned in scientific literature (i.e., Asioli *et al.,* 2017; Maruyama *et al.,* 2021). Substances having a negative connotation, for example, food additives like food colouring, flavours or preservatives are avoided. The packaging may explicitly display positive claims like "natural" or "without colouring and preservatives" etc. According to Fermentationexperts fermenting is a more natural way of preserving products, and at the same time with reduced costs.

As a unique selling point (USP) the meat replacer product is produced using minimal processing. An ancient technique known as solid-state fermentation is a cheap and environmentally friendly process, using minimal amounts of water. This is found beneficial to avoid ultra-processed foods which tend to include many additives and ingredients that are not typically used in home cooking, such as preservatives, emulsifiers, sweeteners, and artificial colours and flavours. Studies have shown links between eating higher amounts of ultra-processed foods and the risk of cardiovascular diseases, thus Fermentationexperts states that this type of product, with limited processing, is healthier to eat.

Product-market fit

This is a clean-label product, which according to Fermentationexperts is in demand by the consumers. This

food trend has also been mentioned by several authors in the scientific literature (i.e., Asioli et al., 2017). Another important challenge this product can solve is removing bitter taste from seaweed.

In addition, increased health challenges related to gut health, make the putative antioxidant-, antimicrobial-, and anti-inflammatory effects fit a consumer demand.

As an additive the potential applications are many, however, all applications has not yet been completely explored by Fermentationexperts.

Target market

The target market for the meat replacer product is the food industry, more specifically the vegan food producer industry. Additional potential markets are meat and bread producers.

Fermentationexperts has identified the US market as the biggest potential market for the meat replacer product. However, as a lot of food producers want to get rid of E-numbers and additives, Europe and Thailand are also potential markets.

Competition and demand

According to Fermentationexperts there is no competition so far. To be able to sell the product a Novel Food approval is needed. Getting Novel Food status from the EU is a lengthy and resource-demanding process. This means that although the product (a meat replacer product with rapeseed cake and seaweed) is already in place, it cannot be taken to market due to this lack of Novel Food approval.

Distribution

Distribution for the meat replacer product has not yet been identified. However, the company have available distribution channels that can be used when they are able to sell the product.

Price

The production cost of a fermented product is lower than other ways of preservation. Pricing strategies have been discussed within the company but will not be settled before they have the approval to sell it.

P8: Designer ALGINATES

Product description

The innovation product designer alginate is produced by SeaMark industry partner Algaia. Alginates represent a wide family of polysaccharides with polymers of mannuronic (M) and guluronic G) acids. Features such as high viscosity, gelling properties, and high stability make alginate an important industrial polysaccharide (Angra *et al.,* 2021).

Algaia's alginates are a naturally occurring polysaccharide produced from brown algae. It demonstrates versatile functionalities as a hydrocolloid with a powerful thickening agent, gelling agent, emulsifier, stabilizer, or moisture retainer in a wide range of applications.

The designer alginate is an alginate produced by using enzymes to produce alginate with higher G-acid content. Alginate from *S. Latissima* is considered a commodity in their original structure, as it is characterized by a high level of M compared to G polymers. There is a significant demand for alginates with high G-ratio as they provide properties of the alginate for many applications, like within medical devices and cosmetics, the two higher-value markets for this polysaccharide. Today, there are a limited number of species that can generate this type of high G alginate. Those species usually come from wild harvests and cannot be scaled up sustainably. Lab-scale testing has shown the possibility of "flipping" the M to G in the cultivated *S. Latissima* using specific enzymes.

For more detail on this product, the processes, and the supply chain, see D8.1 "Characterization of SeaMark Products."

Product strengths

Algaia has identified several strengths of alginate produced from cultivated seaweed.

The general strength of Algaia's alginates is that it is from a natural, plant-based origin. Furthermore, the fact that it is derived from marine sources could also be perceived as an added value compared to other hydrocolloids. Alginate from cultivated seaweed represents a dependable ingredient source with low volatility in supply.

A particular strength of the designer alginates is the possibility to produce an alginate with a high content of G polymers. As a result, designer alginates have much more capacity to produce natural gels, which makes them suited for cosmetics and medical applications, in particular encapsulation of medicines.

Product-market fit

Designer alginate would be the first high Guluronic acid alginate from a cultivated seaweed source, and according to Algaia there is a general lack of G-rich alginate in the market. However, there is still a challenge to identify, isolate, and produce the enzymes needed for the "flipping" of M to G polymer.

Target market

The target market for designer alginate is medical device manufacturers and natural cosmetics. Medical device and cosmetics manufacturers require sustainable sources of natural polymers designed to fit their requirements.

In the cosmetic market Algaia is targeting natural cosmetic manufacturers using the Cosmos standard. The Cosmos standard is an organic and natural certification covering all

aspects of the sourcing, manufacture, marketing, and control of cosmetic products.

Algaia is predominantly focusing on France and US. Germany may also be an interesting market. These target markets are chosen because of local sourcing, short production cycle and low environmental impact will be the key attribute positioning of designer alginates to justify costs. However, there is a global demand for more sustainable sources of alginates, so target markets can potentially be extended to for example USA, where Algaia also has interested customers.

Competition and demand

For designer alginate, Algaia has identified limited competition. For alginate in general there are many competitors. However, according to Algaia most of these competitors are producing alginates with the use of chemicals that should be removed from the manufacturing process and have limited G-acid polymers.

Sourcing and flexibility of the company are quite appreciated by customers especially as Algaia also can handle small volumes of sales which is not the case for most competitors.

Algaia is also among the few companies to get fresh untreated seaweed which does not require chemical preservation most of the year, nor drying. Algaia's production plant is located next to the second-largest brown seaweed source in Europe, ensuring a short supply chain and a regular supply of fresh seaweed. This is also a considerable advantage for reducing transit time prior to processing, producing high-quality alginates, and fulfilling Algaia's sustainability objectives in terms of eco-friendly processing.

Algaia provide high technical R&D support for their customers. As an example, Algaia can help customers establish adequate quality controls to measure functionality, stability, and bioactivity for algal extracts.

Algaia is aware of its weaknesses compared to competitors. One weakness is price competitiveness as their main customers are large multinational groups with great logistic capacities, which leads to a demand for large volumes. Big multinational companies also have the financial capability to purchase large quantities of seaweed if needed. The additional extra cost of designed alginates (enzyme costs) from cultivated seaweed (higher biomass production costs) is also a potential weakness.

Algaia estimates the total market for regular alginate to be over 12,000 tons. Algaia's market share is less than 10%. The proportion of alginates for medical devices is probably around 1000 to 2000 tons and the volumes for cosmetics are, at maximum a few hundred tons. However, both the cosmetics and medical markets are according to Algaia rapidly evolving, so the chances of increased demand are high.

Algaia do believe that additional differentiated product of designer and green alginate will help to grow this market share. However, they point out that the potential supply of cultivated sugar kelp (*Saccharina latissima*), and the production costs mean they will focus on high-value applications with smaller demand in terms of volume and higher willingness to pay.

Distribution

Algaia has identified its distribution channels and is currently using two channels: direct sales and distributors. Direct sales are through key accounts customers on the cosmetic side and a few customers for medical devices. Algaia is also working with a global network of ingredient distributors which have their specialties and network for cosmetic and some medical device sales and a global network of ingredients distributors.

They do not have any issues with distribution at this point. The distribution cost varies but is estimated to be around 10% of the sale cost.

Price

Designer alginate will cost more to produce due to biomass price and enzymatic treatment. The pricing strategy for Algaia is to add up the production costs of designer alginates and properly assess the possible markup by discussions with a few long-time partners. As it initially will be based on small volumes, they will limit sales volumes to each of their customers at a known fixed price. Later they should be able to increase production and thus allocate more to each customer.

At this stage, Algaia doesn't know its customers' exact willingness to pay but aims for the high-end markets. They are confident that they will absorb extra production costs and slight markup on specific niche cosmetic applications and medical devices. It all depends if they get real technical progress out of it or if they manage to pass on the price to their own customer through communication on the origin and traceability.

P9: Fucoidan extraction with enzymes

Product description

The innovation product fucoidan extraction with enzymes, can also be called enzymatically modified co-generated fucoidans. Fucoidan fractions are sulphated fucose-containing polysaccharides with various bioactivities based on their molecular weight, fucose content, sulphate content, branched structure, and other monomer compositions. Fucoidans are a complex series of sulphated polysaccharides found in the cell walls of brown seaweeds (Vo and Kim, 2013).

The fucoidan extraction is produced by Algaia based on sugar kelp supplied by the French company Algolesko. Bioactive properties of fucoidan, such as antioxidant, anticoagulant, antithrombotic, immunoregulatory, antiviral and anti-inflammatory effects have been reported (Wang et al., 2019).

However, a large variation of properties is observed depending on the source material (Cumashi *et al.,* 2007). Several cosmetic products, foods and supplements containing fucoidans are now available on the market and regulatory approval of their clinical use is ongoing in several countries (Fitton et al. 2019). Fucoidans from selected brown seaweed species already have novel food and GRAS approval, which will accelerate the approval of sugar kelp fucoidan. If the market for the fucoidan is feed, these approvals are not necessary.

In SeaMark, the goal is to treat the crude fucoidan fraction obtained with enzymes to improve bioactivities and generate standardized fractions for higher-value applications.
For more detail on this product, the processes, and the supply chain, see D8.1 "Characterization of SeaMark Products".

Product strengths

Algaia has identified several strengths of fucoidan extraction with enzymes. The general strength of Algaia's fucoidan is that it has a natural, plant-based origin. Furthermore, the fact that it is derived from marine sources could also be perceived as an added value. Seaweed fucoidan represents a dependable ingredient source with low volatility in supply. It is also highly biodegradable.

This product has no special differences from other fucoidans, from the source to the composition. However, Algaia believes that the use of enzymes will produce a much more standardized product with bioactivity guarantees, than current fucoidan products on the market.

A unique selling point (USP) is perceived to be connected to the fact that the source is cultivated, thus being technically more sustainable. The perceived advantage of cultivated versus wild harvested is addressed under discussion later in the report.

Product-market fit

According to Algaia the specific problem/need this product solves is that it is a natural product with a strong anti-inflammatory and immunostimulant potential. The natural marine origin from a "vegetable" sustainable resource makes it quite unusual for the targeted markets. One of the main market needs is standardized natural compounds, which potentially can be solved using enzymatic processing. This can improve market penetration for fucoidan extracted with enzymes.

Target market

Fucoidan has been demonstrated to stimulate mammalian immune systems, which makes it highly attractive as a feed additive. Thus, the target market for Algaia's fucoidan product is feed applications. The feed market requires sustainable sources of fucoidan designed to fit their requirements.

Competition and demand

There is a demand for natural fucose to enhance the immune system of animals and humans as well as for cosmetic applications in which those compounds can be used, for example, for anti-ageing effects.

Algaia has identified several companies producing fucoidan fractions. However, the fucoidan is produced from other sources than sugar kelp, and most of them, are from wild stocks. It is difficult to distinguish between companies producing fucoidan such as Marinova, Quingdao Bright Moon Group, Gingko Group Biological, Acadian Seaplant and the companies that are distributing such as Leili, Solabia or SeaHerb. The competing companies are targeting the global market.

Compared to the competitors, Algaia's strength is to some extent based on the functionality and standardization functionality and standardization from the use of enzymes that will guarantee a strong differentiation of this product. In addition, as far as Algaia knows, there is no commercial fucoidan from cultivated sugar kelp to date on the market.

The sourcing and flexibility of the company are quite appreciated by customers especially as Algaia can handle small volumes of sales which is not the case with most competitors. Algaia is among the few companies to get fresh untreated seaweed which does not require chemical preservation most of the year nor drying. Algaia also provides high technical R&D support for its customers. As an example, Algaia can help customers establish adequate quality controls to measure functionality, stability, and bioactivity for algal extracts.

Algaia is aware of its weaknesses compared to competitors. One weakness is price competitiveness. The price of the raw material and its natural composition may make it challenging to compete with the lower production cost of alternative fucoidan, but the European source from cultivated seaweed may be attractive for some markets such as cosmetics where marketing is also a great part of the sales.

Algaia estimates the total market for fucoidan to not exceed 20 tons. Algaia's is not yet in the market with this product. If the feed market is taking over with lower production prices, the market could increase rapidly.

Algaia does believe the market for fucoidan will grow as the social trend, environmental focus and regulatory framework go in the same direction, which is to use more natural polymers and bioactives for all sectors.

Distribution

Algaia has identified its distribution channels and is currently using 2 channels, direct sales, and distributors. Direct sales are through key accounts customers are currently not officially requesting fucoidan products. Algaia is also working with a global network of ingredient distributors which have their

specialities and network. Some of those distributors are interested in fucoidan fractions once those are available and well positioned in terms of composition and bioactivities.

They do not have any issues with distribution at this point. The distribution cost varies but is estimated to be around 15 % of the sale cost.

Price

Fucoidan extraction with enzymes will cost more to produce due to biomass price and enzymatic treatment. The pricing strategy for Algaia is to properly assess possible increases in price by discussions with a few key long-term Algaia partners. As sales initially will be based on small volumes, sales volumes to each of their customers will be limited to a known fixed price. Later they should be able to increase production and thus allocate more to each customer. It will be particularly important to assess the actual benefits/claims that the customers will be able to get from this product. The benefits must be technical and/or in terms of marketing and pricing.
At this stage, Algaia doesn't know their customers' exact willingness to pay. They are confident that they will absorb extra production costs and slight markup on specific niche cosmetic applications and maybe also in the feed market on a cruder version of the product. It all depends if Algaia gets real technical progress out of it or if they manage to pass on the price to their own customer through communication on the origin and traceability.

SWOT analysis

The SWOT analysis outlines the strengths, weaknesses, opportunities, and threats that must be taken into consideration for the respective GTM strategies for the SeaMark flagship products. At the end of this chapter, a summary of the SWOT analysis for both the SeaMark flagship and innovation products can be found.

P2: Bioactive fucoidan

Strengths

Bioactive fucoidan has several potential benefits, both as a nutraceutical and a cosmeceutical. As a nutraceutical product fucoidans claimed key properties are the ability to support gut, immune and cardiometabolic health. An advantage is that fucoidan may represent a comprehensive solution for several health problems instead of targeting only one at a time. As an ingredient in skin health products, bioactive fucoidan claimed key properties are skin barrier protection, reduced ageing, and redness.

The second potential strength of fucoidan is its safety. It has a proven safety record in pharmaceuticals, nutraceuticals, and skincare.

Another strength is the sustainable production of bioactive fucoidan. SeaMark is developing the use of sustainably farmed seaweed rather than wild-harvested seaweed.

The final strength of Oceanium's bioactive fucoidan is the proprietary biorefinery technology which would be difficult to replicate.

Weaknesses

Oceanium needs to scientifically validate their claims of positive health effects by *in vitro/vivo tests* to enter the European market. This will enable them to put health claims on their products.

Opportunities

Oceanium is targeting both the nutraceutical and the cosmeceutical markets, which both are growing. They also focus on the growing global trend of natural and healthy products. They are involved in several research projects to validate health claims and to identify and validate positive health effects which may enable them to differentiate their product from competitors.

Oceanium has a large opportunity to be an early mover in high purity fucoidan produced from sustainably farmed seaweed in the UK for market in the UK, EU, and US.

Other players, specifically Marinova, do have robust portfolios of *in vitro/in vivo* tests that validate health claims, which Oceanium is currently developing.

Threats

There is a threat from existing players, primarily in Asia, although Oceanium claims that their origin and purity are more competitive. Lastly, while Oceanium does have competitive pricing on OCEAN ACTIVES® Fucoidan, production costs might be higher compared to other producers although this is unknown.

P3: Bio-packaging materials

Strengths

A potential strength of seaweed-based bio-packaging materials is that they are suitable for an incredibly versatile range of materials which could offer viable alternatives to fossil-fuel base polymers.

Another strength of Oceanium's bio-packaging materials is the proprietary biorefinery technology which would be difficult to replicate.

Weaknesses

A potential weakness is the high production cost of seaweed-based bio-packaging materials compared to products using fossil-fuel-based polymers.

Opportunities

Seaweed-based bio-packaging represents a sustainable alternative to fossil-fuel-based polymers. They are not susceptible to drought conditions, soil erosion and limited

freshwater availability, thus are a more sustainable alternative than land-based sources of bio-based materials.

Threats

High prices compared to fossil-fuel-based polymers and land-based sources of bio-based materials.

P6: Meat replacer product

Strengths

The meat replacer product has many potential product applications, making it very versatile. The product has many potential benefits such as antioxidant, antimicrobial, and anti-inflammatory effects. In addition, the fermentation process preserves the vitamins and minerals in a much better way compared to other preservation methods. Fermenting seaweed decreases the bitterness, making the product tastier. The meat replacer product is a clean-label product (no additives). Finally, extended shelf-life is a product strength.

Weaknesses

The benefits of the product need to be scientifically verified. The properties of the product in different applications need to be tested out.

Opportunities

The market for clean-label products is increasing, food manufacturers want to reduce additives in food. The product fits the current health trend.

Threats

Fermentationexperts has not identified a specific target market/customer. Competition, demand, distribution, and pricing strategies are not yet in place. Need Novel Food approval to be able to sell the product.

P8: Designer alginate

Strengths

Designer alginate based on seaweed is a natural plant-based product. Seaweed alginate has low volatility in the supply of eco-friendly processing with low usage of chemicals, that is versatile through a wide range of applications. The production can be done without the use of chemicals, making it possible to use the claim “solvent-free” and achieve organic certification.

A particular strength of designer alginates is that, if succeeding, the product will make them more suited for applications where alginate with high G-acidic content is needed, e.g., medical devices. Algaia can provide high technical R&D support for their customers and has the possibility of controlling the Guluronic acid composition, which makes designer alginates attractive for the customers.

Weaknesses

Small production capacity and the use of enzymes make production costs high. There are still challenges in the eco-friendly processing to remove green colour and smell.

Opportunities

The development of a chemical-free production process is an opportunity. Additional differentiated products of designer and green alginate can help Algaia to grow its market share. There is currently only one competitor for seaweed-based alginates. A final opportunity is targeting niche cosmetic producers with a high willingness to pax (luxury segments).

Threats

Price competitiveness can be one threat as their main customers are large multinational groups with great logistic capacities, which leads to a demand for large volumes. Big multinational companies also have the financial capability to purchase large quantities of seaweed if needed.

P9: Fucoidan extraction with enzymes

Strengths

Fucoidan extraction with enzymes based on seaweed is a natural plant-based product. Seaweed fucoidan has low volatility in the supply.

Algaia believes that the use of enzymes will produce a much more standardized product with bioactivity guarantees, than current fucoidan products on the market.

The fucoidan extraction with enzymes is highly biodegradable.

Already have identified 2 possible distributors and have a pricing strategy.

Algaia can provide high technical R&D support for its customers and may have the possibility of producing a more standardized product compared with competitors.

Weaknesses

Small production capacity and the use of enzymes make production costs high.
Has not defined a specific market.
Have not identified a willingness to pay for the products.

Opportunities

There is a demand for natural polymers to enhance the immune systems of animals and humans as well as for cosmetic applications in which those compounds can be used. There is no commercial fucoidan from cultivated sugar kelp to date on the market.
The product is following the trend for social and environmental sustainability.

Already approval for fucoidan from brown seaweed as novel foods and GRAS makes a good chance of attaining these for

this product. However, these approvals are not needed for feed applications.

Threats

As of now, the product has no special differences, benefits or claims compared to other fucoidan products, from the source to the composition. This makes it difficult to differentiate the product from competitors. Thus, Algaia's capability to produce a more standardized product with bioactivity guarantees needs to be proven.

Price competitiveness can be one threat as fucoidan extraction with enzymes will cost more to produce due to biomass price and enzymatic treatment.

Summary of SWOT analysis for flagship and innovation products

Below is an overview of the SWOT analysis of the SeaMark flagship (from D7.1) and innovation products (Table 3).

Table 3: An overview of SeaMark flagship and innovation products target markets, strengths, weaknesses, opportunities, and threats

#	In SeaMark	Product name	Target market	Strengths	Weaknesses	Opportunities	Threats
P1	Flagship	Bioactive beta-glucans	Nutraceutical and cosmetic industry	Health benefits. Water soluble and low molecular weight.	Claims need validation.	Target growing market. Involved in projects to validate health claims	Many competitors. Small-scale producer.
P2	Innovation	Bioactive fucoidan	Nutraceutical and cosmetic industry	Comprehensive solution for several health problems. Sustainable production.	Claims need validation for the European market.	Targets several market segments. Growing market. Early mover.	Existing competition in Asia. Production cost compared to competitors.
P3	Innovation	Bio-packaging materials	Packaging industry	Replace petrol-based ingredients. Versatile application.	High production cost.	Sustainable alternative. Not susceptible to barriers of land-based production.	High price compared substitutes.
P5	Flagship	Pig feed	Pig feed industry	Improves animal health without antibiotics. Improves feed conversion.	Cannot use health claims in EU. Price of product in a low margin market.	Only Western producer. New market segments.	Not able to validate health claims. Small-scale producer.
P6	Innovation	Meat replacer product	Food industry	Versatile application. Health benefits. Tasty. Clean-label.	Claims need validation. Properties of product must be tested.	Target growing market (clean-label and health).	Need novel food approval in EU.
P7	Flagship	Green alginates	Food and cosmetic industry	Eco-friendly processing. Versatile application. Health claims.	High production cost. Small production capacity.	Organic certification. Only Western producer.	Many competitors. Small-scale producer.
P8	Innovation	Designer alginates	Cosmetic industry, Medical device manufacturers	Natural, plant-based origin. High G-acidic content, suited for special applications.	High production cost. Remove colour and smell	Differentiated product can increase market share. Only one competitor.	Price competitiveness. Small-scale producer.
P9	Innovation	Fucoidan extraction with enzymes	Food, feed and cosmetic industry	Natural, plant-based origin. More standardized product.	High production cost. Small production capacity	Demand for natural polymers. First-mover advantage.	Not identified benefits compared to other fucoidan products. Price competitiveness.

Market structure and potential for algae products

This chapter provides information about the market structure and potential for SeaMark innovation and flagship products in the markets for nutraceuticals, pig feed, cosmetics, and alginates.

Nutraceuticals

Nutraceuticals are an umbrella term for nutrition supplement-like products with health benefits that go beyond their basic nutritional value (Chopra *et al.,* 2022). Nutraceuticals cover an extensive range of products, including functional foods such as fortified cereals, dairy, snacks, and beverages such as energy and sports drinks, in addition to the dietary supplement category (The World Bank, 2023). Additional blurred boundary market sectors include cosmeceuticals and nutricosmetics, although these may be considered nutraceuticals (Santini *et al.* 2023). But according to Kalra (2003) nutraceuticals must not only supplement the diet but should also aid in the prevention and/or treatment of disease and/or disorder.

The SeaMark products used in nutraceuticals are bioactive beta-glucan and fucoidan. Bioactive beta-glucans are a bioactive polysaccharide that can be isolated from different sources such as cereal, yeasts, fungi, and algae. Bioactive beta-glucans have documented health benefits such as lowering cholesterol, boosting the immune system, and aiding gut health (Kaur *et al.,* 2020). Bioactive fucoidans are a complex series of sulphated polysaccharides found in the cell walls of brown seaweeds, with properties such as antioxidant, anticoagulant, anti-thrombotic, immunoregulatory, antiviral, and anti-inflammatory effects (Wang *et al.,* 2019).

Market organisation

The overall global nutraceutical market has been estimated to be $450 billion in 2022, and the projected market growth between 2022 and 2030 was estimated to 7.5% CAGR (Compound Annual Growth Rate, i.e., the mean annual growth rate of an investment over a specified period longer than one year). Some niche applications of seaweed-based nutraceuticals exist, such as in functional foods and dietary supplements, but no data on current market size are available (The World Bank, 2023). The seaweed nutraceutical market potential is estimated at $3.95 billion by 2030 (The World Bank, 2023). Several authors have highlighted the nutraceutical market as a very promising opportunity for seaweed-based ingredients (Baghel *et al*., 2023; Santini *et al.,* 2023).

The Asia-Pacific region is the biggest geographical market region, accounting for 31% of the market in 2019 (The World Bank, 2023). Japan alone accounted for about 20% of this market (The World Bank Report, 2023), while according to Yang (2003) China provides 65% of herbal raw materials for the manufacture of traditional Chinese medicine, a category that overlaps with nutraceuticals. India is also an important nutraceutical market, predicted to reach $8.5 billion by 2022 (The World Bank, 2023).

Germany accounts for the largest market share in Europe, followed by the UK and France (The World Bank Report, 2023). In the next decade, above-average growth is expected in China, India, and Brazil (Chopra *et al.*, 2022).

Bioactive fucoidan:

Fucoidan has already been established in the nutraceutical market. The size of the global B2B fucoidan market is estimated at $36.04 million in 2021 and is projected to reach $45.57 million by 2028, at a CAGR of 3.41 % (MarketWatch 2022).

Several commercial fucoidans are marketed by well-known companies, such as Sigma-Aldrich®, Algues and Mer and Marinova® (Anisha *et al.,* 2022). Search on the internet also reveals a large variety of supplement products with fucoidan, from many different companies.

The markets for fucoidan nutraceuticals differ in terms of maturity. In many Asian markets, consumers are aware of fucoidan as a nutraceutical, whereas markets outside of Asia require considerable investment in consumer awareness (The World Bank, 2023). Also, in some markets, fucoidan is found in specialized products. As an example, the fucoidan market in Japan is almost entirely focused on cancer patients (The World Bank, 2023). Consumer fucoidan products in retail in Japan were over 15 billion yen ($116 million) in 2018 (Nagasue 2018; Koe 2018).

Bioactive beta-glucan:

Beta-glucan, used in nutraceuticals, are currently produced from many different sources, such as bacteria, algae, grain, fungus, and yeast. There is no consensus regarding the size of the beta-glucan market; however, a rough estimate based on various market research companies puts the market size at around $500 million. This includes all applications, such as nutraceuticals, food, pharma, cosmetics, and animal health. There is no available estimate of the market share of algae-based beta-glucans.

In the nutraceutical market, beta-glucans are mainly sold as dietary supplements by companies such as Better Being under brands like Solaray. An internet search also reveals many beta-glucan dietary supplements from many different companies, with large price variations.

Competition

Alternative raw materials with proven bioactivity and established market position will be a competitor to seaweed in nutraceuticals, as shown above with beta-glucans. There are many companies producing and selling both fucoidan and beta-glucans, which indicates a highly competitive industry.

Opportunities

The trends likely to drive market growth include the global health trend, influenced by the ageing population, lifestyle diseases and increased consumer awareness. Furthermore,

the rise in the prevalence of several infectious diseases as well as new health threats such as the COVID-19 pandemic, influences market growth (Chopra *et al.* 2022). A final trend that can drive market growth is the focus on more sustainable food sources. Seaweed is considered a pro-environmental food source since its cultivation does not need fertilisers, pesticides, or freshwater (Govaerts, 2023).

As consumers have become more health conscious and environmentally aware, the demand for plant-based and clean-label supplements is growing. "Clean label" is as previously mentioned products produced (Edwards 2013):
" free of 'chemicals' additives, having easy-to-understand ingredient lists, and being produced by the use of traditional techniques with limited processing. "

The packaging of clean label products may explicitly display positive claims like "natural", "without colouring and preservatives," no artificial preservatives," etc. Plant-based supplements, derived from natural sources such as algae, mushrooms, and herbs, are often perceived as more sustainable and healthier alternatives to synthetic or animal-derived ingredients (Innova Market Insights, 2023).

The nutraceutical market displays several health target trends, such as immune support, anti-inflammation, anti-ageing, beauty from within, bone and joint health, gut and digestive health, sports, energy, and weight management (The World Bank, 2023).

Nutraceuticals containing bioactive fucoidan or beta-glucan can potentially provide a wide range of benefits.

Bioactive fucoidan:
A wide range of bio-active properties of fucoidan have been reported, such as antioxidant, anticoagulant, antithrombotic, immunoregulatory, antiviral, anticancer and anti-inflammatory effects (Geetha Bai and Tuvikene, 2021; Wang *et al.,* 2019; Zayed *et al.*, 2022).

As an example, in Japan, many consumers of fucoidan nutraceuticals are cancer patients, and the use of fucoidan for this purpose is an accepted practice in this market. A considerable body of preclinical research exists into these effects. In the last decade, a small number of clinical trials have been carried out to determine the safety and efficacy of supplements for cancer patients (Wu *et al.,* 2022). However, to date, the effects of fucoidan on clinical outcomes in metastatic or recurrent cancer patients have been inconsistent (Wu *et al.*, 2022)

Bioactive beta-glucan:
Beta-glucan is associated with various beneficial bio-active properties such as reduction in glycaemic index and serum cholesterol, control of diabetes, cardiovascular diseases, cancer, and hypertension, immune-enhancing properties, antimicrobial (antibacterial, antiviral) properties, and wound healing activities, among others (Kaur *et al.,* 2020).

Both for bioactive fucoidan and beta-glucan, there is a need for more clinical studies/trials with dietary seaweed and seaweed extract nutraceuticals to verify potential health properties and claims (Wu *et al.,* 2022). It will be important to validate environmental claims on seaweed products by Life Cycle Assessment (LCA) or similar methodologies to measure the environmental impacts of seaweed products or products containing seaweed.

Biorefinery approaches, systems that optimise the extraction of all components, mean that multiple products can be created from a single seaweed biomass (The World Bank, 2023). In the case of large kelps, this can according to the World Bank, (2023) include alginates, fucoidan, beta-glucans and celluloses. A recent paper describes a typical approach for generating multiple product streams from *A. esculenta* and *S. latissima* (Birgersson *et al.*, 2022).

Risks/challenges
The challenges for bioactive fucoidan and beta-glucan are very similar and are reported together in this chapter. There are many clinical trials underway, but our interviews and other sources, such as the World Bank report (2023), show that there is a need for much more clinical work to provide safe products that deliver the claimed health and nutrition benefits. As clinical trials require at least two years and often longer, this could reduce the speed of commercialisation (The World Bank, 2023).

The main challenges are related to:

- Certification of health claims
- Quality and consistency of seaweed supply
- Buyer preferences, awareness, sensory appeal, and adoption. This includes both consumers and professional buyers.

Challenges identified by our respondents in the nutraceutical market, as well as from The World Bank (2023), are described in more detail below.

Availability
An important barrier for ingredient manufacturers' entry is a reliable and safe source of seaweed or seaweed extract (The World Bank, 2023). Variations in available seaweed harvest volumes due to environmental conditions remain a considerable challenge. According to our respondents, batch consistency and reliable suppliers are also critical for nutraceutical producers. Mitigating the risk of inconsistent supply requires that the buyers have several alternative suppliers and storage capacity to keep of enough raw materials (The World Bank, 2023).

Our respondents emphasized the extremely rigorous quality process and confirmed the need for stability of the supply, both related to volumes and, not least, quality. The quality evaluation of seaweed extracts is complex and on the molecular level. Due to large investments to produce nutraceuticals, the manufacturers secure their access to algae by producing their own ingredients (cultured micro-algae). The benefit of own production/cultivation is full control of the raw material and stable, consistent volume and quality. The volume needed for beta-glucans or fucoidans is not that large. However, large amounts of raw material are needed as the content of these components in seaweed is rather low. (see below under drying costs and yield).

Drying cost

Drying cost was identified as a challenge by both our respondents and The World Bank (2023). An inhibitor to the use of whole seaweed biomass includes the costs of drying. According to our respondents, fresh seaweed usually contains more than 90% water by weight and the costs of drying can be considerable (The World Bank, 2023). According to the World Bank, (2023) dried, whole seaweed is generally very stable, with a high salt content that assists preservation. Only if manufacturing processes are in place close to the harvest, wet seaweed can be used for extraction directly after harvest (The World Bank, 2023)

Yield

The yields of the different special components in the seaweed are very small. For instance, the yields of the brown seaweed extract fucoidan and laminarin are usually far less than 10 % wet weight (The World Bank, 2023). As previously mentioned, newer biorefinery processing techniques mean manufacturers can create multiple product streams from one biomass, making production more economically viable (The World Bank, 2023). The need to find improved processing techniques that can optimally make use of all different components available in different seaweed species is mentioned by several respondents as a crucial future step for the success of seaweed production. This is mentioned as important for the yield and sustainable use of seaweed.

Safety hazards

According to our respondents and the World Bank, 2023) product safety is extremely important when seaweed is used for human consumption There may be chemical or biological food safety hazards present in seaweeds (FAO and WHO 2022). Chemical hazards include heavy metals (lead, arsenic, mercury, and cadmium) and high or unknown iodine levels (The World Bank, 2023).

A recent study on seaweed for food purposes available in Europe identified iodine levels exceeding the upper threshold in a variety of seaweed food products (Aakre *et al*. 2021). However, as seaweeds are rarely eaten daily in Europe, this may not represent a public health issue presently (The World Bank, 2023). It can be more important to consider iodine levels in seaweed supplements, as these are designed for daily intake. The iodine content can also be used as a positive health claim (The World Bank, 2023). For example, in the EU, one claim that can be made is that "iodine contributes to normal cognitive function" (European Food Safety Authority (EFSA) Panel on Dietetic Products and Allergies 2010).

Heavy metals and other chemical contaminants must be absent for seaweed to be used in nutraceuticals (The World Bank, 2023; FAO; WHO 2022), or for input into manufacturing. Many countries have guidelines for upper tolerable limits, but there is no international standard (The World Bank, 2023). The development of an internationally recognised standard would ease the global selling and marketing of the products. According to The World Bank (2023), there are also biological hazards which include bacterial and viral contamination.

Compliance costs

The Hazard Analysis and Critical Control Points (HACCP) system is a step-by-step approach to the identification, evaluation, and prevention of biological, chemical, and physical hazards from entering the food production process based on a set of management principles, guidelines, and tools that cover all stages of food production, from harvest to consumption (The World Bank, 2023).

In many countries, whole seaweeds are regularly consumed and have achieved regulatory approval for human consumption. New ingredients often need a Novel Food Approval in Europe and GRAS approval in the US if it is meant for human consumption.

Thus, nutraceutical manufacturers may require a seaweed extract to be generally recognized as safe (GRAS) in the US or classified in the EU list of novel foods in accordance with Regulation (EU) 2015/2283 (The World Bank, 2023). Our respondents in the nutraceutical market confirm that clinical trials are needed to be able to sell ingredients to them.

Capital requirements

It requires significant capital to assist in scaling production and need to account for variations in production (The World Bank, 2023). Thus, for start-ups capital is a key entry barrier (The World Bank, 2023). One of our respondents emphasized the minimal amount of private investment as a major challenge hampering the development of this industry. According to this respondent's view, the lack of private investment is due to a lack of economic sustainability – private companies will not invest if they don't see significant potential for future revenue. The respondent did not believe seaweed would be economically sustainable due to the harsh weather conditions in many places in Europe, creating unstable conditions for seaweed production.

Consumer awareness

For Western consumers, seaweed is an unfamiliar source of food. Thus, a lack of knowledge and awareness of seaweed and its potential benefits to the environment and health may be a consumption barrier (Govaerts and Olsen, 2023). In contrast, Asian markets have a long history with seaweed products (Rao and Ravishenkar, 2022). Several respondents mentioned a lack of consumer knowledge and experience with algae in Europe as a barrier to acceptance and use.

Sensory appeal

A potential challenge with using algae in nutraceuticals is the flavour and smell of the product that may need to be camouflaged. Our respondents said the product could have a very unpleasant taste, and the smell could sometimes resemble wet socks. The process of removing unwanted taste and smell results in more energy-demanding processing.

Regulatory barriers

Regulations of supplements may be regulated differently from country to country (Rojas *et al.*, 2022). A supplement can be classified both as a food or a drug (Visioli 2022). Thus, it may be important to seek guidance in each jurisdiction (The Word Bank, 2023).

DSHEA (the Dietary Supplement Health and Education Act) mandates the safety and labelling of products before marketing (Burdock 2000). According to an investigation from The World Bank (2023), the manufacturer must establish good manufacturing practices, but does not need evidence. In the US, claims may be made about a dietary supplement within guidelines. For example, no statements can be made that imply the supplement affects a disease (The World Bank, 2023).

According to the World Bank (2023) food supplements are in Europe defined as concentrated sources of nutrients or other substances with a nutritional or physiological effect that are marketed in “dose” form. T Food supplements are not medicinal products and cannot exert a pharmacological, immunological, or metabolic action (The World Bank, 2023). Therefore, their use is not intended to treat or prevent diseases in humans or to modify physiological functions (European Food Safety Authority n.d.) (The World Bank, 2023.

It is important to study the regulations needed for the target market(s). In this relation, it may be beneficial to work closely with a potential buyer who has an overview of what is needed for their market and, not least, the requirements they need to buy. The respondents in this sector searched for long-term business relationships and long-term commitments with the possibility of finding solutions together.

Buyer preferences

According to the World Bank (2023) manufacturers need to implement Good Manufacturing Practice (GMP/HACCP); additional certifications – such as organic, halal, kosher, and GMO-free – may also be desirable in certain markets.

According to our interviews, the potential buyers emphasised the need for stable deliveries and quality, certifications and claims, financial commitment, and long-term buyer-seller commitments.

Potential for differentiation (CSF)

According to the World Bank Report (2023) there is a considerable demand for the anti-inflammatory, immune support, cardiovascular health, joint health, and gut health of these products.

Clinical trials are starting to occur, which will help to build confidence in the efficacy of the product and meet the needs of the dynamic nutraceutical market (Santini *et al.*, 2023).

Distribution of power

The nutraceutical market largely consists of large multinational companies. This can make it challenging for smaller ingredient companies to compete in the market or to be able to penetrate the market. The power dependence situation can, in such cases, be very asymmetrical in favour of the large actors. The companies interviewed did, however, emphasise their preference for cooperation and long-term, committed buyer-seller relations, which may make up for this asymmetry.

Cosmetics

The cosmetics market comprises several key product categories, including skincare, haircare, makeup, perfumes, toiletries, deodorants, and oral cosmetics (ref). Cosmetic products have become an integral part of daily routines for people across all genders and ages. With the increasing emphasis on self-care and wellness worldwide, the cosmetics industry has gained immense significance.

The SeaMark products that are aimed for the cosmetics ingredient industry are designer alginates, green alginates, bioactive fucoidan and fucoidan extraction with enzymes. For more descriptions of products see earlier chapters.

Market organization

Fortune Business Insights, (2022) estimated the global cosmetics market to be $299.77 billion in 2022. Further they projected growth by 2030 to $417.24 billion, giving a CAGR of 4.2% during the forecasted period. Recent trends indicate a continual expansion of this industry. In 2022, the global cosmetics market increased 15% compared to the previous year (Statista, 2023).

The cosmetics ingredients market is expected to reach $51.6 billion by 2030 and grow 5,6% CAGR, according to one of the SeaMark partners. There are no available estimates of how big the market share of seaweed-derived cosmetic ingredients is.

Among cosmetics, skincare emerged as the dominant category in 2022, constituting approximately 41% of the global market share, Haircare products followed, accounting for 22%, while makeup products contributed to around 16% of the market. As consumers increasingly prioritize personal care and well-being, the cosmetics industry is poised for future growth and innovation (Fortune Business Insights, 2022).

Growth in population and growth in living standards change the dynamics in the cosmetics markets. Mature markets such as North America and Europe have now been passed by North Asia. In 2022 North Asia was the biggest cosmetic market with a share of 32%, followed by North America 28% and Europe 22% (Statista, 2023).

Different actors use digital media with interactive advertising in their marketing strategies. This is used on social media to push their products online and to boost further demand (Fortune Business Insight, 2022). Beauty influencers on platforms like Instagram, YouTube, and TikTok have a significant impact on consumer choices (Jishu, 2023). Endorsements and reviews from these influencers can propel products to bestseller status or cause a decline in sales (Nielsen, 2022). E-commerce platforms are growing rapidly in popularity, especially among millennials who are the biggest buyers of beauty products online (Statista, 2023).

Competition

There is a growing recognition and scepticism towards the many chemicals and hormone-influencing effects of many cosmetic products. This has resulted in *"shifting consumer preference toward cosmetic surgeries"* (Fortune Business Insight, 2022). Cosmetic Surgeries can alter appearance permanently. It can also help to reduce the daily use of beauty products, and additionally take down usage of synthetic chemicals. Consumers recognise that chemicals may have serious side effects on the body, such as allergic reactions (ibid.).

The partners in SeaMark have identified several potential competitors, both in terms of companies producing fucoidan as an ingredient for cosmetic products, and companies selling cosmetic products with fucoidan. However, in terms of competition, it can be difficult to distinguish between companies producing fucoidan, such as Marinova, Quingdao Bright Moon Group, Gingko Group Biological, Origin by Ocean and Acadian Seaplant and the companies that are selling cosmetic products with fucoidan, such as Leili, Solabia or SeaHerb. For fucoidan, the biggest market is Asia, which is mainly served by Asian companies such as Marinova, Quingdao Bright Moon Group and Gingko Group Biological. However, many of these companies are also targeting the global market.

Opportunities

Focus on personal appearance and well-being has been on a rising trend among the global population and is fuelling the growth of the cosmetics market (Fortune Business Insight, 2022). A growing range of anti-ageing products enters the market with new and innovative and convenient packaging are attracting consumers (ibid.).

Ingredients that are perceived healthier and more natural is on the rise as an important trend. Both organic products with "Clean label", and therapeutic formulations, have been gaining focus among consumers in recent years, and especially after COVID. This has led manufacturers to speed up research and development to seek novel ingredients that can attract consumers (Nielsen NIQ, 2021). A rising numbers of consumers around the world prefer naturally derived products that are non-toxic and safe (Nielsen NIQ, 2019).

Sustainability is also a growing focus in cosmetics, both in terms of recyclable and sustainable materials for the packaging of cosmetic products to reduce carbon emissions, and the use of ingredients in cosmetics that is sustainable (Fortune Business Insight, 2022).

The requirement for green products is expected to rise going forward, due to increased awareness regarding sustainability among the population (Fortune Business Insight, 2022). The organic skincare industry is witnessing significant growth due to changing consumer preferences for sustainable and eco-friendly products. Awareness about the harmful impact of conventional skincare has led the consumers to opt for plant-derived ingredients, free from chemicals, in their pursuit of healthy and glowing skin (Research and Markets, 2023). The report forecasts a 10,2% growth in this market the next five years.

As in the nutraceutical market, there is a clean-label trend in the cosmetic market. The consumers are increasingly focusing on clean labels on cosmetic products. As previously noted, clean-label means the removal of unhealthy additives and the use of natural ingredients. This is actively used when labelling the products to position the products as environmentally friendly and healthy. 1 in 3 new products carry some type of clean label claim, like" no additives," "organic", "GMO-free" and "natural" (Innova Market insights, 2023).

The urge for reduced use of synthetic chemicals, sustainable and clean-label products, brings opportunities for using seaweed as an ingredient in the cosmetic industry. The green alginate, the designer alginate and the fucoidan are natural plant-based products, which can obtain organic labelling.

Risks/challenges

Market growth may be restrained by higher costs of certain products, such as make-up and anti-aging skin care items (Fortune Business Insight, 2022).

Many of the risks and challenges in the Nutraceutical chapter are also prevalent for the seaweed product into the cosmetics industry:

- Availability of consistent supply
- Drying costs
- Yield of target extract
- Safety hazards
- Compliance cost
- Capital requirements
- Consumer awareness and adoption
- Sensory appeal
- Regulatory barriers

Regarding the regulatory aspects, the cosmetic market seems less regulated than the nutraceutical industry. The need and number of clinical trials, claims and documentation are less strict. Still, the cosmetic industry is facing increased regularity. Regulatory agencies, like the U.S. Food and Drug Administration (FDA) and the European Commission, regulate the cosmetic industry, setting safety and quality standards. Compliance with these regulations is essential for market entry and consumer trust (ChemSafetyPro, 2022).

Buyer preferences

Using seaweed compounds in cosmetics is still perceived as something new for consumers according to our interviews. In European countries, one still needs to explain why some compounds from the sea are any better than those coming from land. Thus, much focus is set on promoting sustainability. This includes ecological aspects such as minimizing CO2 emissions during transport and processing, but also the social dimension was mentioned as important. The disparities in working conditions between Asia and Europe were important. Economic sustainability was also a concern, with expectations of upcoming EU regulations. The cosmetic industry was facing much stricter regulations regarding claims, making marketing of their products more difficult.

Increased regulations made documentation of proven bioactivity and functionality of the compounds increasingly important, but not necessarily a prerequisite. Bioactive beta-glucans and fucoidans would for sure be interesting products for them to buy. Attaining lipids from the seaweed would also be interesting in the future.

Today they buy seaweed fresh or frozen and make their own extractions. This format was important as dried seaweed had less bioactivity. If they had the financial resources and competence the ideal would be to source (harvest) the different seaweed species in different areas at different times when the bioactivity for the specific compounds was optimal.

Otherwise, the focus was on products that could benefit the consumers, particularly those suffering from conditions like atopic dermatitis or psoriasis. quality material that could aid skin health was a priority.

Potential for differentiation (CSF)

In a 2023 survey, a significant number of consumers emphasized that the key factor for considering beauty products sustainable was the use of 100 % natural ingredients. Additionally, 45% of respondents in the United States highlighted the importance of products being cruelty-free (Statista, 2023).

The rising demand for cruelty-free products, coupled with the thriving cosmetics industry and inventive marketing tactics, is propelling the rapid growth of vegan cosmetic products (Fortune Business Insight, 2022, Research and Markets, 2023). These trends give the SeaMark products the potential to differentiate as they can claim both sustainability, bioactivity, and naturalness.

Distribution of power

Large, multi-national corporations control the global production of cosmetics and beauty products. The leading company in 2022 was the French company L'Oreal followed by Unilever, Procter & Gamble Co, The Estee Lauder Companies, Shiseido Company, and Beiderdorf (Statista, 2023). These corporations dominate the market with their extensive resources, research capabilities, and brand recognition. The companies often dictate industry trends, invest heavily in research and development, and control a significant portion of the market share (MarketResearch, 2023)

In addition, large retailers like Sephora, Ulta Beauty, and department stores hold considerable power in determining which products reach consumers. They negotiate terms with manufacturers and influence product pricing, availability, and marketing strategies (IBISWorld, 2023).

However, raw material suppliers, including those providing natural ingredients, chemicals, and packaging materials, are found to play a crucial role in the industry. The availability, quality, and cost of these materials can impact product formulations and profitability for skincare companies (Grand View Research, 2023).

Pig feed

Feed material is defined in EUR-Lex No (2011). The principal purpose of a feed material is "*to meet the animal's nutritional needs*" (Bremmers 2016). Seaweed feed materials is listed in the catalogue of Commission Regulation EU No 575/2011 and include *"algae-live or processed, regardless of their presentation, including fresh, chilled, or frozen algae", "dried algae-product obtained by drying algae" that "may have been washed to reduce the iodine content"* (Michalak and Mahrose, 2020). It can be algae oil, obtained by extraction of algae, or algae extract - a watery or alcoholic extract of algae that principally contains carbohydrates (ibid.).).

The organization FEFANA classifies feed additives as speciality feed ingredients (FEFANA, 2023). This means they provide *"micronutrition, technological, sensory, zootechnical functions"* (ibid.). Feeds that incorporate these speciality ingredients can be called "functional feeds" as they promote the growth and

immune systems of animals beyond traditional feeds (Alemayehu *et al.*, 2018).

The SeaMark products used in pig feed are pig feed supplements – a supplementary feed made from fermented seaweed and rapeseed. Piglets and sows seem to gain several benefits from the supplement (Fletcher 2021).

Market organization

The World Bank (2023) estimates the global feed additive market to be $38.86 billion in 2022 and the projected market growth is 3.9% CAGR between 2022 and 2030. The projected seaweed-based animal feed additive market is $1.12 billion by 2030. In their Key light Outlook, The World Bank, (2023) state: "*Seaweed-derived feed additives are expected to outpace other applications over the next five years*". *"There are powerful drivers at work as customers turn to natural alternatives to synthetic products. Improvements in feed conversion ratios are especially promising"* (The World Bank, 2023).

The animal feed industry is already using seaweed as a feed additive and feed ingredient, but as of now it is difficult to get verifiable data on the market size (The World Bank, 2023).

Competition

New feed ingredients or supplements will always compete with the existing feed sources which have established a market position and a known by the producers. The pig-producing farms are often traditional farms that have practised in the same ways for many years, making new feed supplement entry challenging.

Opportunities

Increasing worries among the public regarding the quality and safety of meat, along with the occurrence of livestock diseases, are fuelling the need for animal additives. Not only are farmers driven by financial advantages such as enhanced productivity and better feed conversion ratios, but they are also guided by considerations for animal well-being. (The World Bank, 2023)Seaweed-based products are found to offer distinct advantages, such as reducing the need for animal antibiotics. Moreover, the competitive pricing of seaweed-based products compared to other feed additives enhances their appeal in the market (The World Bank, 2023). Still, feed supplements add costs to the feed.

Seaweed's potential as an alternative feed ingredient arises from its well-balanced amino acid composition, abundant minerals and vitamins, and unique blend of bioactive compounds (Balasse *et al.*, 2019). These elements are found to enhance nutrient absorption and offer various performance advantages for diverse animal species. For instance, certain seaweed species contain polysaccharides with prebiotic effects on animals' microbiomes (The World Bank, 2023).

Studies are showing promising results for seaweed-derived pig feed supplements. The benefits of using these supplements include reduced piglet mortality, improved feed conversion ratios, animal health, and sow productivity (Mahrose and Michalak, 2022). Research has demonstrated support for the application of natural algae extract (MSP) as a solution that modulates the immune system in pig farming (using *Ulva armoricana*) (Bussy *et al*., 2019). Another study indicated that adding laminarin and fucoidan extracts in pig diets for 3 weeks enhanced pork quality (using *Laminaria digitata*) (Moroney *et al*., 2015).

Adding fermented seaweed to pig feeds have shown positive results (Monteiro et al. 2021). The company Ocean Rainforest reported in 2021 that up to 80% of its annual 250-ton seaweed output would be fermented and sold as pig feed. Results from their trials indicated that fermented seaweed, with about 2–5% seaweed inclusion, can "reduce the feed consumption of the sows, their antibodies go up by 30–40% and it has a direct impact on piglet health, reducing mortalities by 3–4%. This results in less need for feed and decreased use of antibiotics, and that the production of piglets increases in addition to the increased profit to the farmers (Fletcher 2021).

According to a pig farmer with 5 years of experience with using fermented seaweed-derived supplements in their pig feed, the positive effect is an overall more stable production with less sickness and disease. It is not possible for them to know exact the cause and effect of the use as they are not doing systematic trials and research. But they were convinced that the seaweed-derived supplement had a positive effect on their production and would not stop using it. For instance, after starting to give the seaweed supplement to their piglets, they experience less diarrhoea (because the digestion system is not developed), which is a big challenge for the piglets. More stable production with less disease reduces the need for antibiotics.

More focus on sustainability issues, reduction of CO2 and "going greener", in addition to increased focus on animal welfare, may give increased opportunities to optimal feeding regimes to keep the pigs healthy and safe to consume.

Risks/challenges

Some of the challenges and risks of seaweed supplements for pigs are like the ones listed in the above chapters. Availability of sufficient volumes of seaweed is a general challenge, but you may also have challenges with the nutritional content of the seaweed, customer onboarding and regulations.

Availability

The production and development of seaweed as a feed additive face several challenges. There are difficulties in creating scalable cultivation methods for different types of seaweed (brown, green and red), as well as challenges in seeding substrates, harvesting at larger volumes, and processing high volumes efficiently (Zhang et al. 2022). Each variety of seaweed requires substantial technical development to extract and analyse the components of interest. (ibid.). Some producers of feed may have specific needs of the

carbohydrate level in their finished product, while those levels may vary during the season in farmed seaweed species. (Olsson et al., 2020). In some seaweeds, such as kelp, there is also a potential drawback considering the relatively indigestible carbohydrate content. (Navarro et al., 2019). To address this, it would be advantageous to conduct more examinations of farmed seaweeds, particularly those that have undergone fermentation (Stévant and Rebours 2021).

Traceability and security throughout the supply chain also represent certain challenges. Wild seaweed is harvested either through beachcombing, cutting, or dredging. Beachcombing, cutting, or dredging are the methods used to harvest wild seaweeds. The environment can be negatively impacted by dredging techniques, as they involve extracting seaweed directly from the seabed (Marine directorate, 2016). Environmental concerns, the need for supply control, and the reality that less than 3% of total seaweed production comes from wild harvesting are compelling downstream product developers to consider vertical integration. This strategy aims to secure a steady biomass supply capable of meeting product demand.

Furthermore, the need for high volumes of biomass by major animal feed customers, coupled with their scepticism about the continuous availability of such large product volumes, can escalate start-up costs for newcomers. This situation can create substantial barriers for market entry (Stévant et al., 2017).

Nutritional quality

The utilization of macroalgae in the production and processing of animal feed supplements could be hindered by the potential bioaccumulation of inorganic elements and heavy metals from seawater, including arsenic, mercury, lead, cadmium, and aluminium, within the macroalgae (Dehbi et al., 2023). Moreover, the nutrient value of processed macroalgae might be compromised due to nutrient depletion, and large-scale macroalgae production demands considerable energy for harvesting and drying. Life Cycle Assessments (LCAs) indicate that these issues, if not addressed, could lead to significant environmental consequences, including increased carbon emissions (Costa *et al*., 2021).

Customer onboarding

Assessing the beneficial effects of seaweed can be a complex and time-consuming process. It often involves testing on a large number of animals in commercial farming settings (Malrose and Michalak, 2022). Suppliers of mixed seaweed components for animal nutrition, such as those in the pig feed industry, require research data to validate the functionality and effectiveness of their products, potentially across various animal species It is essential for them to establish trust with nutritionists and other influential decision-makers in the industry to promote the acceptance of these ingredients. The concept of natural ingredients can be quite novel for some customers, particularly those who have been accustomed to synthetic products over the years. Consequently, these customers often require a period of personal experimentation before they are ready to make a decision to switch.

The pig industry is considered quite conservative and dominated by farmers who are used to doing things in a traditional way and the inclusion of new ingredients is therefore challenging. It is especially challenging when the feed additive means extra costs for the farmer due to higher feeding costs, and the results usually are seen in a long-term perspective. According to one of our respondents, you need to try the special feed for about a year before you can expect to see any results. In addition, the health and welfare of the pigs can be influenced by many different aspects, handling, expertise, hygiene etc., making it difficult to pinpoint the exact benefits or results. According to one of the respondents, it is difficult for the farmers to know the exact cause of reduced diarrhoea in their piglets after giving them the feed with the fermented seaweed. It may be that they were given the feed, or it could be that the sows had been getting the feed, making them healthier and more robust, or if it was the total handling and production. Thus, there is a need for substantial study trials to document the effect.

Regulations

Additives in seaweed feed typically go through several purification processes and standardization steps for the claimed active substance, which performs one or more specific functions. These can be micro-nutritional, sensory, technological or zootechnical (Bremmers 2016). These are also included in animal feeds at small proportions (usually less than 1%). In the EU's feed regulations, "extracts" from seaweed are acknowledged as "feed additives" (Michalak and Mahrose, 2020). EU treats these additives with stricter regulations than feed materials, and they must also undergo more tests. One can find registered additives in seaweed feed that are already on the market in the EU Register of Feed Additives (European Union, 2022).

Macroalgae are typically utilized as providers of bioactive compounds and minerals in livestock feeds, and to a smaller degree, as protein sources. Regarding their composition, the protein and essential amino acid levels in macroalgae can significantly differ, and the digestibility of the protein might be influenced by specific substances in the seaweed. This complexity makes it challenging to broadly categorize the use of entire macroalgae as a protein source, and several species lack sufficient digestible protein to serve as a feasible alternative protein source in animal feed. Challenges such as these are the subject of ongoing research, with scientists striving to improve extraction techniques in the hope of gaining higher levels of protein content from macroalgae. Utilizing biorefinery technology it is feasible to discover cost-efficient and sustainable methods for extracting bioactive compounds like laminarian, fucoidan, and phlorotannin, substances that provide certain health advantages (World Bank, 2023).

While regulatory standards differ from one region to the next, most areas have set forth rules for algae meal and algae extract feeds. For instance, EU has defined upper limits for the presence of arsenic, lead, cadmium and mercury in algae-based feed materials. The upper limit for arsenic in macroalgae feed substances in 10 mg/kg for complete and supplementary pet feeds, and 40 mg/kg for macroalgae meal and macroalgae-based feed substances for livestock (Lähteenmäki-Uutela *et al*., 2021). In the United States, the task of regulating animal feed and pet food falls under the jurisdiction of the FDA. For a product to gain approval as a feed additive, it must be demonstrated to be safe for humans who consume the animals that have been fed with the additive.

Buyer preferences

It is very important to get the same feed composition every time. The quality of the feed needs to be stable. The farmers also need to attain the volume they need and to see the promised effects on the animals/pigs. Trials and documentation would help a lot to get more sold.

Potential for differentiation (CSF)

There is a need for better documentation of the benefits of the feed supplements. You must have research to convince the farmers that this is good business. It is difficult to get higher prices on the pig with marketing on welfare or sustainability, so the producers must convince the farmers in other ways to make them use additional costs on the feed. The sales of organic pig sales in retail have for instance decreased by 35% in the last year. The possible reduction of antibiotic use is a good selling point as this is an important issue in pig farming, but the effect needs to be documented.

Distribution of power

The global pig feed market has several major players including Cargill, Nutreco, and ADM Animal Nutrition. These companies also produce feed supplements. In addition, there are several producers specializing in pig feed supplements like Chr. Hansen A/S, Lallemand Inc. and Novus International**.**

Alginates

Alginate is a type of hydrocolloid, polysaccharides of high molecular weight extracted from plants and algae or produced by microbial synthesis. A hydrocolloid is a suspension of particles in water where the particles are molecules that bind to water and to one another. Besides alginate, other hydrocolloids can be xanthan, guar, carrageenan, and cellulose. The different types have different properties and applications. Alginates are natural polysaccharides consisting of mannuronic and guluronic acids (Angra *et al*., 2021). Commercially available alginate is typically extracted from brown algae, including *Laminaria hyperborea, Laminaria digitata, Laminaria japonica, Ascophyllum nodosum*, and *Macrocystis pyrifera* (ibid.).

High viscosity, gelling properties, and high stability make alginate an important industrial polysaccharide (Angra *et al.,* 2021). The high content of the Guluronic acid gives stronger gelling properties. Seaweed with much Mannuronic acid, like the *Saccharina latissima,* is much more available than the ones with higher Guluronic acid content. This is explained by the biology of the plants.

The SeaMark alginates are green alginate and designer alginate. Designer alginate is alginate produced by enzymatic ways to gain specific types of alginates which have a high content of guluronic acids, which give the alginate better gelling properties. This would make the alginate suited for encapsulation and medical device applications. Green alginate is an alginate that has been manufactured using eco-friendly processes and chemical-free extraction. The goal is to limit and hopefully eliminate, the use of chemicals while reducing CO" emissions. None of these products are yet on the market.

Market organization

The global alginate market was in 2020 valued at $728.4 million with an expected annual growth rate (CAGR) of 5.0% from 2021 to 2028 (Grandview Research, 2021). The market is projected to reach $940.07 million by 2030 (Polaris Market Research, 2022). One of our interview informants describes the alginate market as quite static, with an anticipated growth rate of 2-3% each year.

According to our interview informants, about 80 % of the alginate production happens in China. The quality of the alginate from China varies a lot and is often not suitable for food grade, according to our interviews. In addition, Norway and Chile are big producers. The supply is quite volatile due to the reliance on wild harvest (Grandview Research, 2021).

The stem from *Laminaria hyperborea,* in addition to a couple of brown algae species in Chile, contains a high amount of guluronic acid. In general, alginate is taken from about 8-10 different brown algae species around the world, with *Ascophyllum*, *Laminaria*, and *Macrocystis* as the most widely harvested species.

Alginates are most used in foods and pharmaceuticals and less relevant in their application in nutraceuticals (The World Bank, 2023). However, according to Bi *et al.,* (2022) oligo alginates, created by enzymatic and chemical hydrolysis, are emerging as potential immune support nutraceuticals. In addition, some alginates are used in cosmetics. The US is the biggest market for alginates for food applications, while Europe is bigger for pharmaceuticals (The World Bank, 2023).

Competition

Plant-based alternatives provide competition to the gelatine market growth (Fortune Business Insights, 2022). In addition, the European producers compete in a market dominated by China with 80 % of the volume and long production experience offering lower prices. However, according to informants in the

food industry, there are few available alginate suppliers offering food-grade alginate from China. Their alginate goes more into fabrics.

The alginate market is, according to our informants, a mature market with large start-up investment costs. Building an alginate factory was said to involve a 90-million-dollar investment, making new entry costs high. This is limiting new competition.

For a "designer alginate" and a "green alginate" the main competition will come from regular alginate, which is offered at a cheaper price.

Opportunities

Market actors within foods, cosmetics, and nutraceuticals emphasise the increased focus on sustainability. They mention more conscious consumers and the need for companies to reduce CO2 emissions, making cleaner products safer for the health and better for the environment. This brings opportunities for a greener alginate.
Clean label trends in both the food and cosmetic industry, provide opportunities for more natural alginate – reducing or eliminating the use of chemicals.

The available alginate in the market is dominated by M-acidic alginate, and there is, according to our interviews, a demand for more G-acidic-rich alginate. Thus, the "designer alginate" has an opportunity to serve the markets where this is in demand, be it in the food industry or medical device industry.

In addition to making designer alginate, an opportunity is to explore the cultivation of other species than *Saccharina latissima*. For alginate, there is a market demand for more available G-acidic-rich alginate. However, most of today's cultivation focuses on the same species, *Saccharina latissima*, which contains more of the M-acids and less of the G-acid. Whereas *Saccharina Latissima* is the easiest species to cultivate, other algae species with higher amounts of guluronic acid can create opportunities.

The supply from China is often not according to the specifications needed for the European food industry. Thus, the amount of available food-grade alginate with the right specifications is limited. The demand for alginate is predicted to increase because of more applications. Cultivation of algae for seaweed is therefore seen as a need in the future for preserving natural resources.

Risks/challenges

The risks and challenges for alginate products are much like the ones previously listed (see Chapter about Nutraceuticals); availability of seaweed supply, energy use/drying costs, the yield of target extract, chemical hazards, compliance costs, capital requirements, consumer awareness and adoption and regulatory barriers.

Available volumes of seaweeds are a prerequisite for whatever application, as well as for alginate. As previously mentioned, there is a demand for G-acidic rich alginate, which is a challenge as the cultivated *Saccharina latissima*, contains more of the M-acids and less of the G-acid.

Whereas the production of green alginate, and designer alginate, can reduce or hopefully eliminate the use of chemicals, the production of such alginates is still energy-demanding, with CO_2 emissions.

The processing of green alginate still has challenges in terms of eliminating colour and smell from the end-product. The colour is green, and the smell is too strong, which does not coincide with the buyers' preferences (see next chapter).

Whereas many market segments, such as the cosmetic industry, would like to use clean labels, they are not necessarily willing to pay for it. This was also the perception for food applications. Many consumers may say they want more sustainable food products, but in a choice setting where the clean label costs more, they often choose the cheapest one. In today's situation (2023) with high inflation and increasing prices, many consumers cannot afford to make sustainable choices, according to our respondents. It was also mentioned that the sales of organic products are decreasing.

A recent study on seaweed for food purposes available in Europe identified iodine levels exceeding the upper threshold in a variety of seaweed food products (Aakre *et al.*, 2021). Seaweeds are rarely eaten daily in Europe and should accordingly not represent a public health issue. Iodine levels in seaweed supplements, designed for daily intake, may represent a bigger challenge.

Buyer preferences

Good gelling properties are the main buying criteria in the food market. For medical device applications, and use in cosmetics, this also seems to be the main issue. Good alginate quality is often related to alginate with much guluronic acid. According to one of the respondents, the ideal would be to have alginates where you could "play around" with the G-and M-content in the alginate so that you could find the perfect gelling properties for the different applications.

Alginate for the food application must have a neutral odour, and the colour should be as white as possible. When it comes to particle size it must not contain too much insoluble parts.

Price is always an issue, and for ingredient buyers, it is important to keep the costs down to be able to make money from the end products. The buyers express however limited power to control any pricing as the number of available suppliers is limited, and they need the alginate in their production. However, the pricing of specialized products, like the green and designer alginates can be a challenge if the process makes these products much more costly. Consistent

quality is also important, and the buyers can often experience large varieties in the batches.

Certifications, like the International Featured Standard (IFS), make the buyers' quality assessment easier, but it is not by the respondents perceived as a prerequisite to buy.

For the food industry having vegetarian, halal and kosher certification is helpful as this makes their product more available for different consumer segments. Alginates in this respect, are a hydrocolloid source accepted for all the above-mentioned segments.

Organic alginate would be preferable, but given the chemical process needed to make alginate today, this does not seem possible. Thus, achieving organic certification for the green alginate may prove valuable. Sustainability is as mentioned an issue emphasized by all interview respondents, in all market segments. But again, the additional pricing may be challenging.

Potential for differentiation (CSF)

Seaweed cultivation for other species besides *Saccharina Latissima* to attain more G-acidic-rich alginate seems to have future potential in the alginate market. There seem also to be a potential for the designer, and green alginate given the increased focus on sustainability, but it would need marketing efforts to attain willingness from the buyers to pay extra for this.

Distribution of power

The alginate producers are not that many mainly consisting of big companies. Market entry for newcomers may be challenging due to large investment costs.

The buyers of alginate, like food-producing companies, can vary greatly in size. Small, family-owned businesses may perceive an asymmetrical power-dependence relationship with the suppliers and feel limited influence on the characteristics.

INITIAL ASSESSMENT OF MARKET POTENTIAL

The initial assessment of market potential is done based on input from D7.1 and D7.2, information in this document (T7.3), including feedback from the IPG, and secondary data. Given the complexity and size of the various markets addressed, the basis for the assessment is by no means complete; however, based on the input, some knowledge-based considerations about the future market potential into the market segments can be taken. This will in the next part of the project be followed up by a feasibility study (T7.5).

The initial assessment of market potential will not include:

- Fucoidan extraction with enzymes for food and feed
- Green and designer alginate for cosmetic texture
- Bio-packaging material

The market potential for these products has not been investigated, as food, feed, bio-packing and cosmetic texture products were not included in 7.3, and we were not able to identify potential respondents for these products/market applications. The potential of the various products is divided into short-term (0-18 months), medium-term (18 months-3 years), and long-term (more than 3 years) production scenarios. The short-term production scenarios will identify the 3-4 most promising products for a feasibility study. This is important as the prototype deliveries of SeaMark products must take place within 18 months (rapid prototyping) to gain experience from pilot-scale sales and deliveries (D7.5).

Short-term production scenarios

Based on the interviews with the IPG, other informants and available secondary data, we find that from a short-term production perspective, the following products are most promising:

- SeaMark fucoidan products (bioactive fucoidan and fucoidan extracts with enzymes) for the cosmetic market.
- Bioactive beta-glucans for cosmetics.
- Bioactive fucoidans for nutraceuticals.
- Green alginates for food texture.

SeaMark fucoidan products and beta-glucan for cosmetics

Fucoidan and beta-glucan face quite similar opportunities and challenges in the cosmetic market and are thus presented together. There are already various fucoidan and beta-glucan products in the market with competitive value propositions. Compared to other market applications, like nutraceuticals, the cosmetic industry may present lower complexity in validating claims, at least in Europe. Cosmetic products formulated with naturally derived ingredients are gaining more popularity across many markets. In addition, the demand for eco-friendly products is expected to grow in the future. This fits nicely with the identified strengths of SeaMark fucoidan and beta-glucan products.

Processing complexity, further scaling, competition, and profitability represent potential challenges and must be addressed during the feasibility study.

It will be important to do separate feasibility studies for fucoidan and beta-glucan as the products are different and might face different opportunities and challenges after a feasibility study.

Bioactive fucoidan for nutraceuticals

In recent years, innovative seaweed-based products have been introduced in the nutraceutical market, but the scale are still limited and mostly restricted to niche applications (The World

Bank, 2023). As for cosmetics, products formulated with naturally derived ingredients are gaining more popularity across many markets. In addition, the demand for eco-friendly products is expected to grow. This fits nicely with the identified strengths of SeaMark fucoidan nutraceutical products.

Health claims are important to enable product marketing, and the regulations for validating these differ geographically. In the US the regulations for health claims on nutraceuticals are different than in Europe. It is possible to make qualified structure function health claims in the US that do not require FDA approval, an option which is not available in Europe. Thus, market entry into the US nutraceutical market is possible in a short-term production scenario, while for the European market it is a medium-term scenario due to time attaining scientifically valid claims. Restrictions on health claims, processing complexity, further scaling, competition, and profitability represent potential challenges and must be addressed during the feasibility study.

Green alginates for food texture

Alginates for food applications are a mature market. However, the demand for alginate is predicted to increase because of more applications. Compared to many of the other SeaMark product applications, they present a much lower complexity in validating claims, since there is no need to validate health claims. Green alginates fit nicely with the sustainability and clean label claim trends, but the claims must be approved, and the carbon footprint measured (LCA).

Processing complexity (succeeding with removing colour and smell without using chemicals), further scaling, competition, and profitability represent potential challenges and must be addressed during the feasibility study. Especially willingness to pay extra for green alginates seems to be a challenge because of the general increase in food prices.

Medium-term production scenarios

From a medium-term perspective, the market potential for the following products is promising:

- Bioactive beta-glucans for nutraceuticals.
- Designer alginates for food.
- Pig feed supplements.

Bioactive beta-glucans for nutraceuticals

As for bioactive fucoidan, the demand for naturally derived ingredients and eco-friendly products is expected to grow, which fits nicely with the strengths of bioactive beta-glucans.

However, validating health claims in the EU represents a challenge compared to other markets, such as the US, as clinical trials are necessary to support EFSA claims approval. Clinical trials require at least two years or longer, and thus reduce the speed of commercialisation and make rapid prototyping of this product difficult. In addition, processing complexity, further scaling, competition, and profitability represent potential challenges and must be addressed.

Designer alginate for food

Designer alginate with the potential to alter the content of M- and G-polymers using enzymes, making the alginate optimal for different user applications, seems to have great market potential. There is a high demand for a rich G-alginate for various applications and a limited supply of this type of alginate available. The complexity of the process (managing to identify, isolate, and produce the needed enzymes), and the additional processing costs, which will need solid marketing efforts to make it profitable, give signals of a more medium-term potential.

Pig feed supplements

A similar fermented pig feed supplement to the SeaMark pig feed supplement is already available in the market revealing good results. Farmers get more stable productions with fewer diseases, leading to reduced antibiotic use, which is a serious challenge in many parts of the world. Compared to other applications, the size of the potential market is huge and the time to implement is relatively short. The fermented pig feed supplement presents low processing complexity and no severe challenges to further scaling (The World Bank, 2023)
Flexibility for price is low, though; pig farming is a competitive business where only money is spent if there is a return on it. Therefore, further studies and documentation of the effects will be crucial for the onboarding of potential farmers, and such studies take time.

Long-term production scenarios

From a long-term perspective, the market potential for the following products is promising:

- Designer alginate for medical device.
- Meat replacer product.

Designer alginate for medical device

Entering the medical device market is challenging given the complexity of the approval of the products before acceptance. In addition, the product is not ready to be tested. Thus, the designer alginate for medical devices may have great potential, but more in the long-term perspective.

Meat replacer product

The meat replacer product also reveals great potential as more people are searching for alternatives to animal proteins, but still aim for great tastes. However, for the European food market, Novel Food approval from the EU is necessary due to one of the major components in the meat replacer being classified as novel. Attaining Novel Food approval is a lengthy process, up to 4 years and has already been initiated September 2023. Thus, the meat replacer product, despite the fact it is a ready product, currently is placed in the long-term scenario.

Table 4: Priority matrix for SeaMark products ready for rapid prototyping

Product	Application	Possibility for rapid prototyping
Bioactive beta-glucans	Nutraceuticals	M-T
	Cosmeceuticals	S-T
Bioactive fucoidan	Nutraceuticals	S-T
	Cosmeceuticals	S-T
Bio-packaging material	Packaging	N/A
Pig feed supplement	Pig feed	M-T
Meat replacer product	Food	L-T
Green alginate	Food texture	S-T
	Cosmetic texture	N/A
Designer alginate	Cosmetic texture	N/A
	Medical device	L-T
Fucoidan extraction with enzymes	Feed	N/A
	Cosmetics	S-T
	Food	N/A

The assessment above is summarized in Table 3 with a priority matrix with the different products, applications, and their possibility for rapid prototyping. The green colouring illustrates a potential for prototyping in the short-term (S-T), yellow colouring medium-term (M-T) market potential, orange illustrates long-term (L-T) market potential, while the white with N/A indicates not enough information to evaluate market or out of task scope.

CONCLUSION

This report describes the SeaMark innovation products and the SeaMark partners' initial go-to-market strategy. A SWOT analysis has been carried out to outline the opportunities and constraints (strengths, weaknesses, opportunities, and threats) of the different GTM strategies. Market structure and potential for algae-based products in the markets for nutraceuticals, pig feed, cosmetics and alginates are described and assessed. Furthermore, an initial GTM strategy has been developed for the SeaMark innovation products.

These results provide the foundation for understanding the status of the GTM strategies for the different innovation products. The GTM strategy for the products is quite comprehensive, containing all the necessary elements of a GTM strategy. Even though some elements are not described in detail, this is to be expected as some products are presently at lower TRLs (see D8.1 for a further description of TRLs). The SWOT analysis shows that the products have different profiles in terms of strengths, weaknesses, opportunities, and threats.

The SWOT analysis identifies many issues that need to be further investigated. The validation of claims, and especially scientific validation of health claims, is important for SeaMark products. For some products, like the meat replacer product it is also important to get clean-label approval. Another challenge is to get novel food approval. Altogether this will provide a more comprehensive understanding of the potential opportunities and challenges facing the production of seaweed-derived products.

The initial assessment of market application potential was based on D7.1, D7.2, the SWOT analysis, follow-up interviews with the stakeholders, in-depth interviews with potential buyers and available secondary data. The focus has been on market organization, competition, opportunities, risks/challenges, buyer preferences, potential for differentiation (USPs) and distribution of power. The task for the delivery was to focus on the market for nutraceuticals, pig feed, cosmetics, and alginates.

The assessment of which products and which markets have the best potential for success is a difficult task given the need for careful consideration of the opportunities and challenges revealed in all the different markets. Given the complexity and size of the various markets addressed, the basis for the assessment is by no means complete; however, based on the input, some knowledge-based considerations about the future market potential into the market segments can be taken.

For the rapid prototyping the following products and market applications are chosen given the short-term time perspective and balance between opportunities and challenges:

- SeaMark fucoidan products (bioactive fucoidan and fucoidan extracts with enzymes) for the cosmetic market.
- Bioactive fucoidans for nutraceuticals
- Bioactive beta-glucans for cosmetics
- Green alginates for food texture

A direction that may benefit all producers of seaweed and seaweed extracts is to build strong buyer-seller relationships with the potential buyer of the product and to work closely together in the developing stage. The European market for seaweed is not yet well established, making many buyers sceptical about introducing something new. This scepticism demands a strong marketing effort, which takes both time and resources and the need for long-term perspectives.

By establishing closer buyer-seller relationships the suppliers will have a better understanding of the buyers' preferences, demands and quality criteria. For instance, the notion that the raw material for the seaweed products in the SeaMark project is cultivated is by the stakeholders expected to be a USP. However, the interview results of the potential buyers revealed that this is not necessarily true. For most of the respondents,

the main issue was related to sustainable sourcing, but this could also be by sourcing well-managed wild seaweed.

Further, the biorefinery approach, making it possible to extract maximum value from the seaweed, and produce a diverse and versatile product portfolio, rather than focusing on one that doesn't utilise the biomass to its full potential, seems to have great potential. Several of the respondents emphasized the need to utilize more of the resources to be able to state a sustainable production. Thus, a biorefinery approach could prove very useful.

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APPENDIX 1

Interview guide go-to-market strategies

1. Product

1.1 Could you please describe Product X? What is the product and what is the application?
1.2 Have you identified the strengths of your product (Yes: go to 1.4-1.5; No: go to 1.3)?
1.3 Optional: If not, have you identified potential strengths? What are the potential strengths?
1.4 What are the strengths?
1.5 Does your product have any unique selling points (attributes that can't be copied by competitors)?

2. Product-market fit

2.1 Have you identified what specific problem/need the product solves? (Yes: go to 2.3-2.4; No: go to 2.2)
2.2 Optional: Have you identified potential problem/need does the product solve? (Yes: Go through 2.3-2.4 for potential problem/need)
2.3 What specific problem/need does the product solve?
2.4 Why or how does it solve the problems/needs better or differently from other solutions in the market?

3. Target market

3.1 Who is experiencing the problem/need that your product solves?
3.2 Have you identified a specific target market? (Yes: go to 3.4-3.7; No: go to 3.3)?
3.3 Optional: Have you identified a potential target market(s)? Yes: go through 3.4-3.7 for potential market(s)
3.4 What is the specific industry/customer(s) you are targeting (number)?
3.5 Where is this industry/customer(s) situated?
3.6 What is the size of the target industry/customer(s) in terms of revenue and volume?
3.7 What factors influence whether the target customer decides to purchase your product? (Referrals, primary decision makers etc.)

4. Competition and demand

4.1 Have you identified your competition? (Yes: go to 4.3-4.8; No: go to 4.2)?
4.2 Optional: Have you identified potential competitors? (Yes: go through 4.3-4.8 for potential competitors
4.3 Does anyone else already offer a similar product? Who?
4.4 What customers and markets regions do your competitors target?
4.5 How does your product differ from the competition? What do you offer that others don't? (Description of your product vs. competitor, strengths and weaknesses, price, features, style/design, ease of use, quality, customer support, marketing etc.).
4.6 How does your company compare to the competitors (strengths and weaknesses)?
4.7 Have you identified the demand for your product? How large is the demand?

5. Distribution

5.1 Have you identified a distribution channel for your product? (Yes: go to 5.3-4.8; No: go to 4.2)?
5.2 Have you identified potential distribution channels for your product? (Yes: go through 5.3-5.5 for potential distribution channels)
5.3 What is your distribution channel?
5.4 Do you anticipate any problems with distribution?
5.5 Do you know your distribution costs?

6. Price

6.1 Do you have a pricing strategy?
6.2 Could you describe your pricing strategy?
6.3 Do you know how much is your customer willing to pay for your product (willingness to pay)?
6.4 Additional Comments:

APPENDIX 2

Interview guide Assessment of SeaMark products

T7.3 Investigate market structure and potential for algae products.
Collate and analyse existing quantitative and qualitative information on market structure and potential for **algae-based products** in the market for **Nutraceuticals** (bioactive beta-glucans, bioactive fucoidan) **Cosmetics** (Bioactive beta-glucans, bioactive fucoidan)
Identify and analyse market organization, Degree of competition, Factors influencing supply and demand, Opportunities, Risks, Buyer preferences, Potential for differentiation, Distribution of power, Variability over time.

1. GENERAL INFORMATION

a. Could you please tell us a little bit about the company?
b. Could you please tell us a little bit about yourself and your role in the company?

2. WHAT TYPE OF **ALGAE-BASED PRODUCTS** DO YOU USE IN YOUR PRODUCTION TODAY?

3. WHAT TYPE OF BETA-GLUCANS/FUCOIDANS/ALGINATES DO YOU USE IN YOUR PRODUCTION?

4. CAN YOU TELL US ABOUT YOUR USE OF **ALGAE-BASED** PRODUCTS IN YOUR PRODUCTIONS?

5. WHAT ARE THE BENEFITS ASSOCIATED WITH (USE OF) ALGAE-BASED …?

6. WHAT ARE THE CHALLENGES/WEAKNESSES ASSOCIATED WITH (USE OF) ALGAE-BASED …?

7. CAN YOU DESCRIBE THE VALUE-CHAIN FOR …?

9. HOW IS THE AVAILABILITY OF …. IN THE MARKET?

10. DO YOU EXPERIENCE A LARGE COMPETITION IN THE MARKET FOR (ALGAE-BASED?) …?

11. COULD YOU TELL HOW THE MARKET FOR (ALGAE-BASED) … DEVELOPING?

12. WHAT ARE YOUR MOST IMPORTANT QUALITY CRITERIA FOR (ALGAE-BASED) …?

13. WHAT ARE YOUR MOST IMPORTANT BUYING/PRODUCTION CRITERIA FOR (ALGAE-BASED) …?

14. WHAT QUANTITY OF THE PRODUCT DO YOU NEED FROM A SUPPLIER TO MAKE IT INTERESTING FOR YOU TO BUY?

15. WHAT DO YOU PERCEIVE AS THE BIGGEST OPPORTUNITIES IN THE MARKET FOR (ALGAE-BASED?) ….?

16. WHAT DO YOU PERCEIVE AS THE BIGGEST RISKS IN THE MARKET FOR (ALGAE-BASED?) ….?

17. BUSINESS- AND PRODUCT IMAGE

a. In your opinion, what is a sustainable product?
b. What is important for you to know about a product in terms of sustainability?
c. How important is sustainability (raw material, processing, distribution) for a product like this? Does sustainability affect your willingness to pay? Why/Why not?
d. How important are claims for a product like this (health claims if identified)? Does this influence your willingness to pay?

18. ARE THERE ANY FACTORS THAT ARE IMPORTANT TO YOU REGARDING …. THAT WE HAVE NOT COVERED?