AlgaePro BANOS

CONSUMER ANALYSIS AND ACCEPTANCE OF SELECTED BUSINESS CASES

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LIST OF ABBREVIATIONS

Abbreviation	Description
D	Deliverable
BANOS	Baltic and North Sea (BANOS)

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ABSTRACT

Algae, a versatile and sustainable renewable resource, offer a promising solution for various product applications without the need for freshwater, arable land, or added fertilizers and pesticides. Despite this potential, their utilization remains underexploited. The AlgaeProBANOS project, funded by Horizon Europe, aims to address this by harmonizing economic development with social and environmental goals in the Baltic and North Sea regions. The project supports six business pilots focusing on diverse sectors such as food, nutraceuticals, cosmetics, textiles, feed, and plant biostimulants, leveraging both microalgae and macroalgae to innovate and scale up production.

To ensure market readiness and consumer acceptance, the project conducted an extensive literature review on the acceptance of algae-based products. This report synthesizes findings from 69 peer-reviewed papers spanning eleven years, highlighting the enablers and barriers to consumer acceptance across the six key sectors food, nutraceuticals, cosmetics, textiles, feed, and plant biostimulants. Key findings reveal that health and environmental benefits drive consumer interest, but barriers such as unfamiliarity, taste, and accessibility persist. The research underscores the importance of clear communication, transparency, and strategic marketing to enhance end consumer acceptance. Despite the novelty of the topic and limited specific studies, the report provides a comprehensive framework for understanding consumer dynamics, offering valuable insights for businesses, policymakers, and researchers aiming to integrate algae-based products into mainstream markets and promote sustainable consumer behaviour.

PICTURE 1: PHOTO BY BEN WICKS ON UNSPLASH

1. INTRODUCTION

Algae are a versatile and sustainable renewable resource which can be utilized in a wide range of product applications. They can be cultivated without using freshwater, arable land, or added fertilizers and pesticides (Ullmann and Grimm 2021). However, the potential of algae utilization has yet to be fully exploited.

The AlgaeProBANOS project, funded under Horizon Europe, addresses the challenge in the Baltic and North Sea (BANOS) area on how to harmonise economic development with social and environmental goals in line with the Mission Ocean. There is a rising demand for green healthy natural consumer and biobased products, and algae can become the biomass resource of the future. Both the Baltic and North Sea engulf the necessary conditions to scale up production and produce both commodity and sophisticated algae-based products. AlgaeProBANOS brings together 26 experts and industry partners from the BANOS area and beyond, to accelerate product development and market access of sustainable algae solutions.

The AlgaeProBANOS project aims to accelerate the development of sustainable and innovative algae-based products in the Baltic and North Sea to make the EU a world leader in algae product development and to support coastal societies and local economies. The project backs six business pilots, aiding SMEs and start-ups in launching eight algae-based products in the areas of food, nutraceuticals, cosmetics, textiles, feed and plant biostimulants. Value chains are based on microalgae and macroalgae, sourced in the Baltic or North Sea or from recycled resources. Innovation takes place in iterative loops with assessments to secure maximum robustness, efficiency, and sustainability. Furthermore, value chains are built with end-users' needs put in the centre, through engaging users in co-creation activities, to ensure maximum uptake. Digital tools are developed to support all actors from biomass producers to consumers.

The AlgaeProBANOS pilots are innovative start-ups and SMEs from the Baltic and North Sea region which are developing a range of algae-based products from across a number of value chains. There are four macroalgae pilots using Fucus, Saccharina, Sargassum, Furcellaria and/or Kelp and two microalgae pilots.

PICTURE 2: PHOTO ON ISTOCKPHOTO: BLADDER WRACK

In order to smooth the products' entry into the market and to ensure that consumers accept them, this consumer analysis (project deliverable D6.1) summarises the relevant available literature about consumer acceptance of algae-based products in the above-mentioned product groups. The analysis also aims to highlight limitations and gaps in current research about consumer acceptance of algae-based products.

This report focuses particularly on end consumer acceptance of products containing, or made of, algae in these six sectors:

- food
- nutraceuticals
- cosmetics
- textiles
- feed
- plant biostimulants

The six pilot partners

SJY is producing **food** snacks and ingredients for the mass market from kelp. They use algae produced in the Arctic Sea, from which they develop and create sustainable vegan algae food products and ingredients.

oceanBASIS is producing innovative products from the sea for natural **cosmetics** and healthy **food**. The aim of their work is to be able to make the health-promoting effects of fucoidan available to people in the form of a **nutraceutical**.

ALGIECEL is introducing new **cosmetic** & **feed** ingredients from microalgae. In the project they are further developing and commercialising their microalgae oil-fraction and protein-fraction as ingredients within the **cosmetic** and **feed** industries.

Origin by Ocean manufacture algae-based functional ingredients to substitute existing chemicals. Within the project they are researching rheology modifiers and functional ingredients from brown seaweed (Fucus, Saccharina, and Sargassum) that can be used across the **textile** industry.

Power Algae is turning CO_2 from waste into microalgae products. In the project they will upscale their own cultivation and processing technology as well as test alternative approaches. They focus on **feed** ingredients and **nutraceuticals**.

Vetik carries out research into the creation of **biostimulants** from *Furcellaria* within the project. Their aim is to create scalable, commercially-viable solutions for the development of natural sea-based ingredients with applications in the **food** and **feed** industry.

Structure of the analysis

A dedicated section is reserved for each product sector, encompassing their definition and contextualization, followed by specific findings on the enablers and barriers to their consumption. Business actors searching for insights will easily find the most relevant section to their specific product area(s). The results of this analysis will be of interest for companies working with algae product development, but also assist retail actors in understanding consumer acceptance in these fields for the listed products. Civil society actors in the area of sustainable agricultural products and production could be interested, as well as policy actors shaping financing and supporting structures for sustainable production and consumption. The report concludes with a comparison of the product groups, an identification of limitations in the literature on consumer acceptance and a proposition of a direction for further research.

1.1. Methodology

This report aims to assist and support the project partners and society in further understanding what drives and hinders end consumers' acceptance of the six algae product groups: food, nutraceuticals, cosmetics, textiles, feed and plant biostimulants. This is done by conducting a desk and literature research based on scientific peer-reviewed papers until the beginning of 2024. Scientific non-peer-reviewed, or non-scientific literature was not included to ensure credible and high-quality evidence.

In this deliverable we selected 69 papers to be reviewed, with a period covering eleven years, from 2012 to 2023. Date bases like Google Scholar and University Catalogues (e.g. Leiden University) were screened. The papers were selected on the basis of a key-word search of terms like “consumer acceptance” AND “algae” OR “seaweed” AND “food” OR “cosmetics” OR “nutraceuticals” OR “textiles” OR “feed” OR “biostimulants”. Papers concerned specifically with consumer acceptance of algae in the Baltic and North Sea region were deemed of high relevance, followed by those focused on consumer acceptance of algae in Europe, considered of medium relevance. Any article dealing with consumer acceptance of algae

elsewhere was considered to be of lower relevance. Papers analysing algae-based products, but not consumer acceptance were also considered as lower relevance. Through the literature search, we arrived at a total of 20 relevant articles for consumer acceptance of algae-based food and one for feed.

When widening the scope to products similar to algae, we arrived at five on nutraceuticals, five on cosmetics, and two on textiles. A table that summarises the examined studies and papers on algae acceptance of food products can be found in the respective product type section. Papers that do not specifically refer to both algae and consumer acceptance, are only included in the references. For the other product groups, no table was created due to a lack of studies specifically focusing on algae-based products.

In order to achieve the report's aim of understanding the barriers and enablers of consumer acceptance of the six product groups, the following objectives were formulated:

1. **Map consumer acceptance data for respective product types:** to understand the available literature about consumer acceptance of the specific algae product group.
2. **Examine barriers for acceptance:** to identify and analyse the perceived barriers that consumers associate with each algae-based product group, such as taste, safety concerns, or lack of awareness.
3. **Explore enablers for acceptance:** to investigate factors that facilitate consumer acceptance for each algae-based product group, including positive perceptions, health benefits, environmental sustainability, or marketing strategies.

These objectives provide a comprehensive framework for understanding the dynamics of consumer acceptance, barriers, and enablers associated with algae-based products across the various groups.

Limitations

Due to the scope of selecting peer-reviewed scientific literature particularly focusing on consumer acceptance of algae-based products, research publications especially beyond food appear to be limited. Whereas the literature on the benefits offered by algae to various product groups exists, literature specifically on consumer acceptance of these products barely does. This might be partly explained by the novelty of the topic. The report focuses on (non-commercial) end consumers as the primary target audience, rather than focusing on customers within the supply chain (such as e.g. animal farmers that would be "end-users" of algal animal feed). This narrows the research, especially for two of the product groups, namely feed and plant biostimulants, as these do not directly target end consumers, but rather customers, in this case, farmers. There were no publications about the end consumer acceptance of nutraceuticals, plant biostimulants, cosmetics and textiles using algae, and only one for consumer acceptance of meat derived from animals fed with algae-based feed.

The alternative strategy adopted to identify interesting patterns was to research the consumer acceptance of products marketed with claims that hint at benefits comparable to those of algae-based products (e.g., "green", "climate-friendly", "sustainable", "plant-based"). More specifically, for the nutraceutical's product group, the research was extended more broadly to the category of plant-based food supplements. With regards to textiles, results were limited to "sustainable textiles". Concerning cosmetics, the research was extended to the acceptance of other natural ingredients in cosmetics and claims like "sustainable" and "green" cosmetics. Despite these limitations, comparisons and a meta level analysis was conducted and can be found in the respective chapters and at the very end of the report.

2. CONSUMER ACCEPTANCE OF SELECTED ALGAE BUSINESS CASES AND PRODUCTS

This chapter describes the state of the art of consumer research for the specific product groups food, nutraceuticals, cosmetics, textiles, feed and plant biostimulants.

2.1. Food

In recent years, there has been an increase in interest in algae as a food source in the Western diet. In the literature, few studies have focused on algae from the perspective of consumer behaviour. These studies have used different factors to study algae food consumption in different countries. In total, we retrieved 20 papers focusing on algae from a consumer perspective in the last 10 years. In the following sections, we present the main factors influencing the consumption of food containing algae.

Familiarity and neophobia

The absence of an algae food culture is a crucial challenge for adopting algae food products in Western countries. A few studies have explored the effect of food neophobia, the fear or dislike of new things, on consumers' acceptance of food containing algae. These studies (Birch et al. 2019; Losada-Lopez et al. 2021; Palmieri and Forleo 2020; Wendin and Undeland 2020) underlined the negative impact of food neophobia on consumer attitudes towards food containing algae that was hindering consumption.

For example, Losada-Lopez et al. (2021) found a negative effect of neophobia on consumers' interest in eating algae in restaurants before and after consumption. This study also investigated whether neophobia negatively affects consumers' perceived health, wellness and naturalness attributes and consumers' beliefs in a chef's presentation of an algae dish. The results showed no significant influence of neophobia on perceived attributes and chefs' presentations (Losada-Lopez et al. 2021). However, food innovative consumers (referring to the tendency to purchase new food products) are more likely to try algae-based foods (Govaerts and Olsen 2022, 2024).

Studies have explored different ways to introduce algae into people's diets. Grahl, Strack, Weinrich, and Mörlein (2018) investigated the acceptance of three food products (pasta, sushi and jerky) containing algae across France, Germany and the Netherlands. They found that products that consumers were most familiar with, were the most widely accepted. Of the three products, pasta was preferred by the consumers. Algae can also be used as a salt substitute. According to a panel of consumers, a recent study has explored the acceptable level of algae as a salt replacement in bread (Gorman et al. 2023). The study results indicated that the panel accepted 10% and 20% salt-reduced breads using algae. Consumers expressed dissatisfaction with breads replacing more than 20% of salt with algae due to a pronounced aftertaste and insufficient saltiness. Algae can also be used as a condiment in sweets like chocolate, which, according to Salgado et al. (2023), can be a good strategy to introduce algae to consumers. Moss and McSweeney (2021) studied consumers' emotional responses and intentions to eat bread, fish fillet, cheese, noodles, yoghurt, and sausage containing algae. The study found that Canadians were most positive towards bread and had the highest intention to consume it. However, they disliked yoghurt and sausage containing algae (Moss and McSweeney 2021). According to Wendin & Undeland (2020), snacks and bread with algae were the food categories that consumers were most positive about.
In France, Germany and the Netherlands, another study also examined consumers'

acceptance of meat substitutes based on algae (Weinrich and Elshiewy 2019). The study indicated that people with a low meat consumption habit were more positive towards algae as a meat substitute than meat lovers.

Health motivations

The literature underlines that the health benefits of algae in food significantly influence people to consume it (Birch et al. 2019).

> *Marine algae are rich in nutrients. Depending on the type, they can be a good source of proteins and amino acids. Some algae are naturally rich in polyunsaturated fatty acids (omega-3 and -6), which can prevent cardiovascular disease. Finally, macro-algae are rich in fibre and minerals (for example, iodine, iron and calcium) and vitamins (A, D, E and K).*

Weinrich and Elshiewy (2019) underline the importance of health benefits as a motivation among consumers to substitute meat with algae. Palmieri and Forleo (2022) found that environmental and health characteristics and availability of algae are important consumption drivers. A recent study (Young et al. 2022) examined the factors influencing the consumption of algae food products among young adults in Australia. They found that nutrition, health benefits and taste were the main drivers. According to Blikra et al. (2021), the main reason for consumer scepticism towards algae is the lack of knowledge regarding its nutritional value and health benefits. Govaerts and Olsen (2022) showed a positive relationship between awareness of health consequences and intention to eat food containing algae and between ascription of responsibility and intention. Intention and food innovativeness are both predictors of algae consumption. The findings suggest that consumers are motivated to consume food containing algae if they believe these products have positive health consequences. In addition, the results indicated that environmental consideration plays a vital role in the formation of intention. In another paper, Govaerts and Olsen (2024) identified the consumer groups which perceived themselves as healthy, and valued their well-being highly, were more inclined to consume algae food products.

Environmental motivations

Macro algae cultivation positively impacts the ecosystem as it helps maintain biodiversity, provides coastal protection and improves water quality (Sondak and Chung 2015). Moreover, unlike agriculture, which puts pressure on land and water, algae farming does not consume fresh water, pesticides or added fertilizers (Ullmann and Grimm 2021).

These environmental properties positively affect consumers' perceptions, attitudes, and consumption of food containing algae. For instance, in a pilot study, a survey conducted by Wendin and Undeland (2020) also showed that Swedish consumers had a positive attitude towards consuming algae for environmental reasons. In another study, Govaerts and Olsen (2023a) expanded our understanding of the factors affecting algae food consumption. Their results indicated that Norwegian consumers had a positive attitude towards algae consumption and perceived it as unique and natural. The perception of the naturalness of algae food triggered a positive response from consumers. Moreover, consumers with ethical and environmentally motivated values were more likely to accept algae food. This was in line with Govaerts and Olsen (2024), who identified that consumers who highly value the environment were more inclined to consume algae food products.

Accessibility, affordability, diversity and knowledge

Young et al. (2022) identified lack of accessibility, unaffordability, and a lack of diversity as major barriers to algae food consumption among young adults in Australia. Other studies found similar results: in the UK, Embling et al. (2022) found

that taste and familiarity were strong drivers of algae consumption, whereas Redway et al. (2022) indicated that consumer perception of algae sensory aspects, consumers' knowledge of health benefits and risks, affordability, and availability were common factors influencing algae consumption.

Govaerts (2023) highlighted the limited availability of algae food products in retail outlets and the lack of knowledge regarding their preparation and consumption as significant barriers to consumption. The authors also identified that the more consumers perceived they could buy food containing algae in the store, the more likely they were to consume food with algae (Govaerts and Olsen 2023a). Govaerts (2023) underlined that consumers do not associate algae with pleasure, which remains a significant challenge.

Finally, Palmieri and Forleo (2022) explored the factors most capable of impacting Italian consumers' willingness to eat algae. They found that information about algae, previous experiences and a positive disposition toward algae are crucial factors capable of improving consumer acceptance.

Conclusions

This review provides the emerging European algae sector with valuable insights into consumers' motivations to eat food containing algae. The literature review underlined that consumers lack familiarity with algae as it is not a part of Western food culture.

While the novelty of food containing algae presents an opportunity for new culinary experiences, it can simultaneously serve as a barrier for individuals who are reluctant to try new flavours and textures. The unique taste of algae may appeal to adventurous consumers seeking novel gastronomic experiences, but for others, unfamiliarity may deter them from buying food containing algae. The lack of knowledge about cooking, preparing and using algae in European cuisine is also a barrier to consumer adoption. The literature also highlights the lack of accessibility of food containing algae in stores as a factor hindering consumer purchase. Perceived high prices and the lack of variety of algae products are also barriers to consumption.

Health and environmental issues are factors increasingly taken into consideration by consumers. In the case of algae, the results from this review indicated that perceived sustainability and healthiness are two important factors inciting consumers to consume food with algae. Furthermore, the results from the literature review indicate that the consumer segment which is the most likely to consume food with algae are people who value the environment and their health and are innovative. Finally, the literature highlighted little sensorial association as consumers are unfamiliar with algae's taste, smell and textural properties. Introducing algae to consumers through daily products (e.g. bread, pasta, chocolate and snacks) has been recommended.

PICTURE 3: PHOTO ON ISTOCKPHOTO: DRY ALGAE

TABLE 1: A SUMMARY OF PREVIOUS WORK ON CONSUMERS' ALGAE PREFERENCES, ACCEPTANCE, ATTITUDES, MOTIVATIONS AND CONSUMPTION

AUTHOR(S), YEAR	SCOPE AND CONCEPTUALIZATION	METHOD	KEY FINDNGS
Grahl et al., 2018	Explore consumer acceptance of familiar vs. unfamiliar algae food products in France, Germany and the Netherlands.	Interviews, survey, mixed-method approach, ANOVA	Pasta was the most widely preferred product due to consumer familiarity with pasta.
Weinrich & Elshiewy, 2019	Explore consumer preferences for meat substitutes containing algae in France, Germany and the Netherlands.	Survey, conjoint analysis	Underlined the importance of health benefit and price as factor influencing consumer acceptance of meat substitutes containing algae.
Lucas et al., 2019	Explore the determinants of algae consumption and label preference in France.	Survey, multinomial probit model	Identified attitude as an important predictor of algae consumption and label preference.
Birch et al., 2019	Explore who are likely to eat algae in Australia, using health consciousness, responsibility and food safety concerns, neophobia, symbolic food consumption and snacking behavior.	Survey, binary logistic regression	Identified education, familiarity, food neophobia, the symbolic value of food consumption, health consciousness and snacking behavior as significant predictors of the likelihood of eating algae products.
Wendin & Undeland, 2020	Investigate consumers' attitudes and preferences toward different categories of algae as food in Sweden.	Survey, descriptive statistics	Consumer showed positive attitudes towards algae. Snacks are the preferred algae products. Algae products were the most popular among young men.
Palmieri & Forleo, 2020	Explore consumer eating habits, neophobia, attitudes and perceptions of algae and profile consumers in Italy.	Survey, principal component analysis and cluster analysis	Identified algae environmental and health characteristics and algae availability as important drivers of consumption.
Palmieri & Forleo, 2022	Investigate the importance of information on consumers' acceptance of eating algae in Italy.	Survey, factor analysis, logistic regression	Identified information about algae, previous experiences and a positive disposition towards algae as crucial factors.
Weickert et al., 2021	Investigate consumer evaluation of the potential of algae cultivation systems together with information.	Survey, structural equation modeling	Showed the importance of nutritional and environmental qualities in consumer acceptance of cultivation systems in combination in Germany.
Losada-Lopez et al., 2021	Explore the influence of neophobia, perceived wellness, health and naturalness on interest in eating algae in Spain.	Survey and tasting session	Neophobia affected intention to consume algae. No influence of neophobia on health, wellness and naturalness perception.
Moss & McSweeney, 2021	Evaluate consumer emotional responses to algae food products in Canada.	Survey, ANOVA	Underlined the influence of hunger status, food neophobia and lifestyle on their emotional response.
Young et al., 2022	Explore the motivations that drive young Australians to eat algae.	Survey, content analysis, descriptive statistics	Identified nutritional and taste qualities as the main drivers. Identified price, accessibility and diversity as barriers to algae consumption in Australia.
Embling et al., 2022	Explore the consumer acceptability of algae-based food products in the UK.	Survey, MANOVA	Emphasized the importance of taste and familiarity as factors in the acceptability of algae-based food products.
Govaerts and Olsen 2022	Explain and predict algae consumption using an extended version of the norm activation framework	Survey, structural equation modeling	The result support the ability of the norm activation framework to explain the intention of consuming algae. Innovative food consumers are more likely to consume algae food products.

AUTHOR(S), YEAR	SCOPE AND CONCEPTUALIZATION	METHOD	KEY FINDNGS
Redway *et al.* 2022	Explore algae consumption frequency, perceptions of algae as a food, drivers and barriers of algae consumption in the UK.	Survey, descriptive statistics	Sensory aspects of algae, knowledge of health benefits and risks, affordability, and availability were common factors influencing whether participants would increase their algae consumption. Awareness of the nutrition and health effects of algae consumption was low.
Govaerts and Olsen 2023a	Investigate the antecedents for consumers' attitudes towards algae food products in a representative sample of Norwegian consumers	Survey, structural equation modeling	Norwegian consumers form their positive attitudes towards algae food products based biospheric values and their beliefs that these products are healthy and natural
Bolduc *et al.* 2023	Study the efficacy of education on ecosystem services of kelp aquaculture as marketing material for kelp end products	Survey, ANOVA	Indicate that consumers value the environmental benefits of algae in terms of regulating services, pricing remains a key determinant in their purchasing decisions. It underscores the importance of considering both environmental education and pricing strategies in promoting algae
Gorman *et al.* 2023	Aim to evaluate whether the amount of salt in bread could be reduced and the change in sensory properties be mitigated by the inclusion of brown algae.	Tasting session, ANOVA	Consumers accepted 10% and 20% salt-reduced breads using algae. The breads with > 20% were associated with strong aftertaste, along with not being salty enough for the consumers. The salt reduction label had a negative impact on the consumers' liking.
Govaerts 2023	Compared consumers' personal norms, attitudes, intentions and behavior towards algae food products between Norway and the UK	Survey, descriptive statisitcs, ANOVA	Underlined that Norwegian respondents were willing to eat algae products more frequently than UK respondents. Norwegian perceived algae as healthier, more natural, tastier, more unique, newer, safer and more accessible than their UK counterparts
Salgado *et al.* 2023	Identify the profile of possible buyers of three different types of chocolate enriched with algaes and the sensory drivers of liking.	Tasting session, logistic regression	Showed that enriching chocolate with algae can be a good strategy to introduce algae into Portuguese markets. Hedonic consumers suggested to be potential buyers.
Govaerts and Olsen 2024	Identify and profile segments of algae consumers in the UK	Survey, cluster analysis	Emphasized how environmental values and self-identity can effectively group consumers into homogeneous segments. Identified a specific consumer group in the UK that is more likely to consume algae food products.

2.2. Nutraceuticals

Food supplements have been defined in various ways since their first appearance in the market. Nutraceuticals is the most widely used term, but dietary supplements or medical devices are used as well (Nicoletti 2016).

> *The definition of a nutraceutical is a "food or part of it that provides the body with medical or health benefits, including the prevention and treatment of a disease" (Ishak et al. 2017, p. 1).*

These products often consist of a combination of primary metabolism substances such as carbohydrates, vitamins, and proteins, along with secondary products like flavonoids, terpenes, polyphenols, etc., typically found in raw plant materials or extracts.

Algae are rich in both types of substances and as such, their introduction into the nutraceutical market represented a turning point for it (Nicoletti 2016, p. 2). Consequently, in addition to their nutritional value, algae are increasingly being marketed also as "functional foods". Like nutraceutical, this term describes foods that contain bio-active compounds, or phytochemicals, that may positively impact health (Wells et al. 2017).

So far, there are no studies which specifically deal with consumer behaviour towards algae-based nutraceuticals, but rather on plant-based supplements.

Product attributes and advertisement

The main barrier to the consumption of plant-based supplements is the frequent use of scientific language in drug and supplement marketing to persuade consumers to purchase products advertised as promoting health. This often leads to confusion among consumers. Often, consumers do not understand health claims as they are intended and this causes scepticism among them (Egan et al. 2011, p. 750). Another important consideration relates to the source of information on the product: generally, manufacturers are less trusted by consumers than governmental agencies (Herath et al. 2008; Hailu et al. 2009).

Gaur et al. (2017) found a random sample of Indian students to evaluate supplements mainly based on "taste, color, sweetness, smell, stickiness, texture, appearance, and overall acceptability; whereas for women, the characteristics were taste, color, smell, mouthfeel, appearance, and overall acceptability" (p. 163).

Although some studies found price to be a key variable for consumers' willingness to purchase functional foods, Herath et al. (2007) actually found consumers to be generally flexible with regards to cost, prioritizing other product attributes.

Gender, health and socio-economics

Women were chosen in some studies due to the fact that they often taste food before feeding it to their children; as a result, their acceptance of a product is crucial (Gaur et al. p. 168). A study by Egan et al. (2011) found a higher consumption rate among women as compared to men. In the United States, university students frequently intake protein powder, amino acids and ginseng. There, too, women, especially with a graduate-level education and who self-rated their health as good to excellent, and worked out regularly – displayed a higher intention to use dietary supplements. A higher income was also associated with a more positive consumer attitude towards food supplements (Egan et al. 2011, p. 747).

In general, when it comes to the reasons driving purchase, most users cited health benefits (Egan et al. 2011, p. 749). A positive perception of the general health benefits associated with plant-based food supplements is an important predictor of use; and as a result, those most likely to purchase such products are individuals with a healthy lifestyle (pp. 748, 749). This aligns with the findings by Teoh et al. (2019), which also show that the perceived benefits of nutraceuticals are a commonly cited reason for purchasing and consuming them.

Conclusion

No articles dealing specifically with consumer acceptance of algae-based nutraceuticals were identified, and even the literature on consumer acceptance of plant-based food supplements is fairly limited, with most of the papers dating back to the early 2000s, which makes it difficult to generalize their findings to today´s trends and to the developments associated with algae introduction in the industry. However, the broad patterns identified might play into consumer acceptance of algae nutraceuticals as well, although this remains a topic to be further researched.

In the case of supplements designed to be fed to children, mothers are a key target group to focus on. Incorporating functional ingredients into widely accepted food products might be a valuable strategy to improve the taste and appearance as well. We can expect this, in turn, to indirectly strengthen consumer acceptance. Furthermore, women – particularly when they are financially comfortable and educated – seem to consume dietary supplements at higher rates than their male counterparts. University students are also a receptive target group to these products. Consumers who conduct an active and healthy lifestyle are most likely to consume plant-based supplements. In fact, the first reason for consumption of food supplements are the health benefits. What is

vital in marketing efforts, however, is to ensure clarity and use simple language for consumers, given that scientific jargon confuses them (Egan et al. 2011, p. 750)

2.3. Cosmetics

Marine algae have been gradually gaining considerable attention in the cosmetic industry (Thiyagarasaiyar et al. 2020). Algae contain substances which can be incorporated into cosmetics, as they can act as hydrating and solidifying agents in skincare. Furthermore, algae components can positively affect tanning, wrinkles and the ageing of skin. As a result, they are valuable ingredients for sunscreen, lipsticks, eye-liners and other cosmetic products. Certain algae species have been found to have antibacterial, anti-fungal, antioxidant and anti-inflammatory properties. (Aslam et al. 2021).

As for the business case of nutraceuticals, studies focused on the barriers and enablers of consumer acceptance of cosmetics made with algae were not found.

Most of the literature approaches the broader category of green or sustainable cosmetics. Therefore, three articles on the factors which drive consumers to purchase the latter will be used to, highlight patterns which may apply to algae cosmetics as well. A more targeted analysis of consumer acceptance of cosmetics made with algae, when further data is available, is nevertheless crucial for future research.

Functionality, health and environmental motivations

The key barrier to consumption of sustainable and natural cosmetic options arises if these are not more functional than the conventional alternative: consumers will normally not purchase sustainable cosmetics, unless they are also equally or more effective than traditional alternatives (Amberg and Fogarassy 2019, p. 9).

There is a growing awareness of the detrimental effects of air pollution on skin health. Consumers appear to be increasingly interested in purchasing cosmetics which can safely and effectively mitigate skin complications (Ali et al. 2020). Algae fulfil this role effectively, presenting a significant opportunity for the cosmetic industry. Moreover, consumers have been found to place great value in having a full head of hair, which is associated with youth. In these cases, alopecia or hair loss can cause not only dermatological but also psychological discomfort. As a result, given that some species of algae can usefully treat alopecia, they lend themselves as an attractive option (Aslam et al. 2021). Furthermore, consumer preference has been shifting towards natural cosmetics as opposed to synthetic options, mainly due to the adverse side effects associated with the latter (Thiyagarasaiyar et al. 2020, p. 1). The undesired impacts of chemicals included in cosmetics have encouraged consumers to look for less harmful, and more natural alternatives. Given that algae are reported to be safe for human health, and that they can be processed using eco-friendly techniques for extraction, they possess unparalleled potential (p. 2). A growing number of consumers are using a varied range of natural cosmetic resources and materials (Amberg and Fogarassy 2019). Health and environmental awareness have the potential to be crucial drivers of consumer behaviour even in the future (Amberg and Fogarassy 2019, p. 13). Similar to the case of nutraceuticals, women appear to be more open to buying natural cosmetics and self-care products as compared to men, particularly if they have children, shop for the entire household and play a central role in taking care of the safety of the family through their product choices (Singh 2019). Other studies, however, found no significant differences in the purchase intentions of male and female consumers towards natural cosmetics: both display general positive attitudes towards cosmetics made of natural ingredients (Tengli and Srinivasan 2022, p. 12).

Conclusion

If cosmetics made with algae are to follow the same patterns identified for green and sustainable cosmetics, we can expect the three main factors to play a crucial role in consumer acceptance.

Firstly, health motivations may be a driving force behind the growing interest among consumers toward green cosmetics, which is prompted by an increasing awareness of the effects of environmental condition such as air pollution and its effects on skin health.

The second element which positively impacts consumers' acceptance of sustainable cosmetics is that they are often perceived as more natural and safe options, compared to their synthetic and chemical counterparts. Consumers are increasingly aware of the undesirable effects of chemicals in cosmetics on health and the environment and are therefore looking for less harmful and more natural alternatives. As far as the environmental side is concerned, algae can be processed using eco-friendly techniques for extraction, on top of generally being less contaminant and detrimental to the environment.

Lastly, functionality is an important consideration which can both drive and hinder consumer acceptance of – and the subsequent decision to purchase – green and sustainable cosmetics: this is because, unless the latter are also more (or equally) effective than their traditional counterparts, as well as cost-competitive, consumers are unlikely to purchase them. This means that it is crucial to ensure that price and functionality are taken into account when marketing green cosmetics, while still emphasizing their naturalness and their health and environmental benefits.

2.4. Textiles

The production of clothing and textiles more broadly is one of the world's most polluting industries (Boström and Micheletti 2016). In the case of medical textiles, a pressing concern is that chemical finishes or coatings are often used. Seaweeds are a promising alternative which can be used for the finishing of such textiles (Janarthanan and Kumar 2018). Macroalgae, in fact, contain "phycoerythrins and carotenoids, which represent valuable pigments for the textile finishing industry" (Moldovan et al. 2017, p. 2). Furthermore, macroalgae contain compounds, particularly polysaccharides, which can be used as "homogenisers and thickeners in diverse products (...) and for textile printing (to promote the thickening of the reactive dyes paste or to create common colour pastes to apply in the normal printing fabric process, making printed fabric more wash-resistant)" (Pardilhó et al. 2022, p. 8).

Another challenge which characterises the textile industry is unclear and untransparent labelling, and lack of knowledge from consumers. The latter often have a poor understanding "about the production process of a product and therefore cannot internalize the environmental externalities in their purchasing choices" (Ziyeh and Cinelli 2023, p. 2). Eco-labels aim to tackle this, and they are increasingly sought after by consumers. In order to be effective, however, they need to be simple and intuitive (Ribeiro et al. 2023).

One further aspect tied to textile production which is of notable concern is dyeing: textile dyeing using synthetic pigments has negative environmental and human health impacts. The stages of mordanting and dyeing fabric entail a considerable degree of water waste, and "generate chemically loaded water" (Mutaf-Kilic et al. 2023, p.1). The contaminated water deriving from the process significantly threatens biodiversity. However, for years, there has been no sustainable alternative to synthetic dye due to its higher cost, wide variety, and accessibility. Growing awareness of the risks associated with the dyeing of textiles has led researchers to try and identify natural resources which can

substitute synthetic colours, including pigments in micro algae (Mutaf-Kilic et al. 2023, p.2). While microalgae pigments show promise as textile dyes, this potential application remains largely unexplored. They are a natural resource and can produce pigments in a number of colours, which makes them a versatile option for the textile industry (Mutaf-Kilic et al. 2023, p. 4).

Knowledge, familiarity and transparency

One challenge to more sustainable textile consumption is that there is an overall lack of awareness and familiarity concerning bio-based products (Fernandez et al. 2023). Furthermore, a number of consumers struggle to understand sustainability information on product labels, and they find it difficult to access sustainable alternatives. There is a gap in terms of consumer knowledge and awareness, which calls for the provision of more transparent information and for efforts to educate consumers about sustainable practices and their impact (Ribeiro et al., 2023, p. 20). We are observing a shift in consumers' attitudes towards more sustainable textile consumption. For this to be exploited, however, easier access to, and information on sustainable products are crucial (Ribeiro et al. 2023).

Consumers seem to be increasingly looking for transparency and when purchasing textiles, becoming more proactive players in creating a fairer and more sustainable economy. As such, socially responsible companies who are transparent about their labour policies are likely to attract conscientious consumers. Furthermore, today, consumers seem to seek eco-certifications (Ribeiro et al. 2023, p. 20), indicating a growing preference for environmentally sustainable practices. Demand is growing for information on the health and safety benefits of products, particularly of the extent to which they contribute to CO2 savings. For garments, an additional attribute which is valued by consumers is the lower social impact compared to conventional products (Fernandez et al. 2023).

Conclusion

In line with the chapter above, one can say that if algae are used in textile production and finishing, these textiles would then follow the same patterns identified for sustainable textiles with regards to consumer acceptance and we can reasonably expect several factors to play a crucial role.

The pursuit of more sustainable textile consumption faces significant hurdles due to a lack of awareness and familiarity with bio-based products, as well as challenges in understanding sustainability information on product labels and accessing sustainable alternatives. Bridging this knowledge gap requires a concerted effort to provide transparent information and educate consumers about sustainable practices. However, there is a notable shift in consumer attitudes towards sustainability, with increasing demand for transparency and eco-certifications. Socially responsible companies that are transparent about their labour policies are likely to attract conscious consumers. Additionally, consumers are increasingly seeking information on the health, safety benefits, and CO_2 savings associated with products, as well as their lower social impact compared to conventional alternatives. To capitalize on this shift, easier access to sustainable products and comprehensive information are essential.

2.5. Feed

Algae's properties and benefits extend far beyond their incorporation into products for direct human consumption: algae, in fact, possess considerable potential to be used as mineral additives in the feed industry (Kovač et al 2013). Studies have shown that feeding hens with special microalgae has proved to be commercially profitable (Pulz and Gross 2004). A large number of nutritional and toxicological evaluations demonstrated the suitability of algae biomass as a beneficial feed supplement (Becker 2007, p. 210). However, according to Shields and

Lupatsch (2012), biomass in algae can only serve as a supplementary source, rather than fully replace manufactured minerals or vitamins in animal feeds. Another benefit of using algae in the feed industry is constituted by the pigments contained in microalgae, which may be used to colour products and also to improve their texture (Kovač et al. 2013, p. 4). Spirulina, particularly, is often said to be the most complete and rich source for organic nutrition in nature; this biomass is widely used as a feed supplement in aquaculture as well as in the poultry industries (Hasan and Rina 2009). Adding microalgae to the diet of pigs, cows, chicken, sheep, other domestic animals and aquatic organisms has been demonstrated to have positive nutritional impacts by a number of experiments (Kovač et al. 2013). Even when used in small amounts, algae seem to deliver significant health benefits, including an improved immune system, metabolism, gut function and stress resistance (Shields and Lupatsch 2012). As mentioned above, algae biomass lends itself as a sustainable ingredient in the aquaculture feed industry: given that improved fish nutrition can reduce waste and, thus, contribute to food security and sustainability, incorporating algae might be promising. It has been demonstrated, that some particular microalgal species are well-suited to be used to feed tilapia, the second most farmed fish globally (Ahmad et al. 2022, p. 9522). Algae-based feeds have been proven to enhance nutritional quality and the growth of fish (Ahmad et al., 2022). Several compounds which are found in algae, particularly microalgae, are of high nutritional value for aquaculture - thus, enhancing their concentration and exploitation, combined with increasing the availability of microalgae-based ingredients in farmed fish feeds is promising (Idenyi et al. 2022, p. 7).

Environmental motivations

The global demand for animal-based protein is rising due to population growth and increased middle-class incomes. We need alternative protein sources in livestock and fish feed to meet this demand and avoid further pressure on land (Röös et al. 2017; Vigani et al. 2015). Algae has emerged as a promising alternative due to its high protein content and its ability to be cultivated independently of land (Holman and Malau-Aduli 2013). Despite these obstacles, consumers are increasingly interested in alternative protein sources, particularly those concerned with animal welfare and environmental impacts. Understanding consumer acceptance and preferences is crucial for successfully integrating these alternative feedstuffs into the market.

The literature on algae as alternative protein sources in food reveals several barriers to their acceptance in Western consumer markets, including disgust, food neophobia, product availability, and price concerns. However, very little research has been conducted regarding consumer acceptance of animals fed with algae feed. To the best of our knowledge, the only study focusing on this topic is by Altmann et al. (2022), who examine consumer preferences for chicken meat produced using algae and insect feed ingredients. Their results indicate that a segment of consumers is prepared to accept algae as feedstuffs. Algae-based feeds are highly accepted by environmentally conscious consumers. Moreover, providing information on the positive environmental effects and sustainability attributes of algae feed has the potential to shift consumer acceptance (Altmann et al. 2022). However, since low price is still a significant driver for meat purchase and consumption (Milford et al. 2019, p. 7; Anusha Siddiqui et al. 2023), consumers' willingness to pay a premium compared to a switch to alternative proteins, should be examined.

Conclusion

In conclusion, there is a significant need for further research to comprehend the potential impacts on feed ingredients and the likelihood of producers embracing algae-based feed in the EU market. Upcoming studies must investigate the consumer's inclination towards specific labelling standards for incorporating algae in animal feed.

Additionally, future research should focus on understanding the consumer's readiness to pay a premium for food products from animals fed with algae-based feed across European markets.

2.6. Plant biostimulants

The agricultural sector is under an increasing pressure to shift towards natural alternatives to synthetic chemicals, including pesticides and fertilizers, in response to evolving international regulations and laws (Rouphael et al. 2020) as well as to alleviate the environmental burden. Biostimulants, including those made with algae, "represent a sustainable and effective alternative or complement for their synthetic counterparts, bringing benefits to the environment, biodiversity, human health and economy" (Rouphael et al. 2020, p. 1). The role of the end-user, in this case farmers, and the potential in changing agricultural practices is barely researched (Leimann, 2020) and is influenced by interconnected factors such as knowledge, values, personal attitudes, socio-economics and social norms (Lamarque et al. 2014, Lastra-Bravo et al. 2015). In terms of end consumer acceptance of food produced using algae-based biostimulants, this is even less explored. It could be researched also for application in private gardens.

The behaviour and attitude of end consumers towards algae-based biostimulants is a topic which has, as of today, hardly been researched. When investigating consumer perception of microalgae production and biorefinery, Lafarga et al. (2021) found that overall, "consumer knowledge about microalgal biotechnology and the health and environmental benefits of this valuable raw material are scarce" (p. 1). Research on how knowledge and familiarity increase consumer acceptance of food products was already described in the food chapter, but is also reported for other products. This gives rise to the hypothesis that these two factors can also increase the acceptance of biostimulants; however, this is still to be explored.

Conclusion

Algae-based biostimulants emerge as a sustainable and effective option, offering benefits to the environment, biodiversity, human health, and economy. However, despite their potential, the perception and understanding of end consumers regarding algae-based biostimulants, that were used to produce food they purchase, remain largely unexplored. More research needs to be conducted, particularly on the drivers and barriers to use and acceptance of such products.

3. DISCUSSION AND CONCLUSION

Algae-based products hold promise across diverse sectors, driven by consumer motivations such as health consciousness, sustainability, and functionality. However, barriers such as novelty, accessibility, and consumer education persist, necessitating strategic approaches to overcome them. Emphasizing health benefits, naturalness, and environmental sustainability can enhance consumer acceptance, while addressing concerns regarding taste and unfamiliarity. Collaborative efforts between industries, policymakers, and researchers are essential to meet evolving consumer demands and drive market penetration of algae-based products.

3.1. Key Findings

Key findings from the analysis of consumer acceptance of algae-based products across the six product groups food, nutraceuticals, cosmetics, textiles, feed and biostimulants.

Food

- Consumers lack familiarity with algae and algae-based products, hindering acceptance.
- The novelty of algae-based products presents opportunities for adventurous consumers but acts as a barrier for others.
- Growing health and environmental concerns increasingly motivate consumer acceptance for innovative alternatives.
- Accessibility, high prices, and lack of knowledge are widely reported barriers.

Nutraceuticals

Limited research exists on algae-based nutraceuticals, prompting a focus on plant-based alternatives:

- Health-conscious consumers tend to be more receptive to nutraceutical products.
- Clear and transparent communication is essential for fostering consumer trust in nutraceutical brands.

Cosmetics

Limited research specifically on algae-based cosmetics, therefore focus on sustainable and "green" cosmetics:

- Health motivations and perceptions of naturalness, safety and sustainability drive acceptance.
- Functionality and cost competitiveness are crucial factors.

Textiles

Limited research specifically on algae-based textiles, therefore focus on sustainable textiles:

- Lack of awareness for and understanding of the topic hinders acceptance.
- Transparent information and credible certification attract conscious consumers.
- Health, social and environmental benefits drive interest and increase demand.

Feed

Limited availability of studies on consumer acceptance:

- Further research needed on consumer preferences and labelling standards.
- Understanding the sustainability benefits is crucial for end consumers' willingness to pay a premium for meat from animals fed with algae-based feed.

Biostimulants

Limited research on consumer acceptance, since end consumers are barely targeted by existing studies.

- Further investigation needed to understand consumer preferences.

These findings underscore the importance of addressing consumer concerns, emphasizing health and sustainability benefits, and enhancing accessibility and communication to drive acceptance of algae-based products across the sector

3.3. Consumer acceptance of algae-based products

The acceptance of algae-based products among consumers varies across the analysed product groups. In the **food** sector, consumer willingness is hindered by factors such as novelty, lack of familiarity, and accessibility, while health and environmental concerns serve as motivators. **Nutraceuticals**, although lacking specific research on algae-based products, exhibit similar patterns, with emphasis on health and transparent communication to increase consumer acceptance and trust. "Green" **cosmetics** are driven by health motivations, perceptions of naturalness, and environmental sustainability, mirroring consumer trends in sustainable products overall. **Textiles** face challenges of awareness and understanding sustainability information but show a growing demand for eco-friendly alternatives. **Feed** products require further research on consumer preferences and labelling standards. Plant **biostimulants** necessitate deeper exploration of consumption drivers and barriers.

If algae-based ingredients or products are used to provide a more sustainable and healthier alternative, common themes that emerge in consumer acceptance are familiarity, health and environmental concerns, naturalness and functionality. This is highlighting the importance of addressing consumer concerns while emphasizing health, sustainability, and functionality throughout all product groups. In addition of addressing a lack of knowledge through clear and transparent consumer information and labelling.

3.4. Limitations and future research outlooks

Despite the insights gained, several limitations, but also avenues for future research exist. Firstly, this review is likely to be missing studies in its overview, although we were using a broad approach to search for literature. Publication bias, leading into more effective studies being also published more often, is likely to have also influenced our results. Due to a lack of studies specifically looking into consumer acceptance of algae-based products, the scope for reviewing papers was widened to products marketed with claims that hint at benefits comparable to those of algae-based products, e.g., "green", "climate-friendly", "sustainable", "plant-based" for these product groups. The lack of specific studies on consumer acceptance of algae-based cosmetics, textiles, feed, nutraceuticals and plant biostimulants highlights the need for focused investigations into drivers and barriers of consumer acceptance towards algae-based products within these sectors. Additionally, the generalizability of findings across different regions and demographic segments warrants further exploration to research if consumer acceptance differs between regions, but also for locally versus imported algae products. Future research should delve into the nuances of consumer preferences, including health and environmental concerns, taste preferences, price sensitivity, and cultural influences. These research projects should elaborate, if factors influencing consumer acceptance of algae-based food products can be transferred to other algae-based products, like cosmetics, textiles and nutraceuticals as well. Longitudinal studies tracking consumer attitudes and behaviours over time can provide valuable insights into evolving trends and market dynamics. Moreover,

interdisciplinary collaborations integrating consumer psychology, marketing strategies, and sustainability science can offer comprehensive perspectives to inform product development and market strategies. Ultimately, addressing these research gaps will facilitate the successful integration of algae-based products into mainstream consumer markets, contributing to sustainable and healthier lifestyles and ecosystems. In order to achieve this, algae-based product development should be planned in a circular manner from the very beginning on, in order to use most of the properties of the algae throughout its value chain.

REFERENCES

Ahmad, A., W. Hassan, S., & Banat, F. (2022). An overview of microalgae biomass as a sustainable aquaculture feed ingredient: Food security and circular economy. Bioengineered, 13(4), 9521-9547.

Ali, A. et al. (2020). The impact of airborne pollution and exposure to solar ultraviolet radiation on skin: mechanistic and physiological insight. Environmental Science and Pollution Research. doi:10.1007/s11356-020-09280-4

Altmann, B. A., Anders, S., Risius, A., & Mörlein, D. (2022). Information effects on consumer preferences for alternative animal feedstuffs. *Food Policy*, *106*, 102192.

Amberg, N., & Fogarassy, C. (2019). Green consumer behavior in the cosmetics market. Resources, 8(3), 137. https://doi.org/10.3390/resources8030137

Anusha Siddiqui, S., et al. (2023). Consumer acceptability of plant-, seaweed-, and insect-based foods as alternatives to meat: A critical compilation of a decade of research. Critical reviews in food science and nutrition, 63(23), 6630-6651.

Aslam, A. et al. (2021). Algae as an attractive source for cosmetics to counter environmental stress. *Science of The Total Environment*, 772, 144905.

Becker, E. W. (2007). Micro-algae as a source of protein. Biotechnology Advances, 25(2), 207–210.

Bioenergy — IPCC. (n.d.). IPCC. Retrieved from https://www.ipcc.ch/report/renewable-energy-sources-and-climate-change-mitigation/bioenergy/

Birch, D., Skallerud, K., & Paul, N. (2019). Who eats seaweed? An Australian perspective. Journal of International Food & Agribusiness Marketing, 31(4), 329-351.

BIT. (2020). A Menu for Change: Using behavioural science to promote sustainable diets around the world. The Behavioural Insights Team. London, UK.

Bolduc, W., Griffin, R. M., & Byron, C. J. (2023). Consumer willingness to pay for farmed seaweed with education on ecosystem services. Journal of Applied Phycology, 35(2), 911-919.

Boström, M., & Micheletti, M. (2016). Introducing the sustainability challenge of textiles and clothing. Journal of Consumer Policy, 39, 367-375.

Egan, B. et al. (2011). An overview of consumer attitudes and beliefs about plant food supplements. *Food & Function*, 2(*12)*, 747-752. https://doi.org/10.1002/jsfa.11178

Embling, R, Neilson, L, Randall, T, Mellor, C, Lee, MD, and Wilkinson, LL (2022) 'Edible seaweeds' as an alternative to animal-based proteins in the UK: Identifying product beliefs and consumer traits as drivers of consumer acceptability for macroalgae. Food Quality and Preference, 100(April), 104613. doi:10.1016/j.foodqual.2022.104613.

Fernández, V., Laborda, E., Del-Busto, F., & Bartolomé, C. (2023). Social Perspectives towards Biobased Products and Textiles. Sustainability, 15(3), 2284.

Gaur, S., et al. (2017). Omega-3-fortified lipid-based nutrient supplement: Development, characterization, and consumer acceptability. Food and Nutrition Bulletin, 38(2), 158–171.

Gorman, M, Moss, R, Barker, S, Falkeisen, A, Knowles, S, and McSweeney, MB (2023) Consumer perception of salt-reduced bread with the addition of brown seaweed evaluated under blinded and informed conditions. Journal of the Science of Food and Agriculture, 103(5), 2337–2346. doi:10.1002/jsfa.12473.

Govaerts, F. (2023). Factors Influencing Seaweed Consumption: The Role of Values, Self-Identity, Norms and Attitudes.

Govaerts, F., & Olsen, S. O. (2022). Exploration of seaweed consumption in Norway using the norm activation model: The moderator role of food innovativeness. Food Quality and Preference, 99, 104511.

Govaerts, F., & Olsen, S. O. (2023). Environmental values and self-identity as a basis for identifying seaweed consumer segments in the UK. British Food Journal.

Govaerts, F., & Olsen, S. O. (2024). Environmental values and self-identity as a basis for identifying seaweed consumer segments in the UK. British Food Journal, 126(4), 1456-1472.

Grahl, S., Strack, M., Weinrich, R., & Mörlein, D. (2018). Consumer-oriented product development: the conceptualization of novel food products based on spirulina (Arthrospira platensis) and resulting consumer expectations. Journal of Food Quality, 2018.

Hasan, M. R., & Rina, C. (2009). Use of algae and aquatic macrophytes as feed in small-scale aquaculture: A review (No. 531). Food and Agriculture Organization of the United Nations (FAO).

Hailu, G., Boecker, A., Henson, S., & Cranfield, J. (2009). Consumer valuation of functional foods and nutraceuticals in Canada. A conjoint study using probiotics. Appetite, 52(2), 257-265.

Herath, D., Cranfield, J., & Henson, S. (2008). Who consumes functional foods and nutraceuticals in Canada?: results of cluster analysis of the 2006 survey of Canadians' Demand for Food Products Supporting Health and Wellness. Appetite, 51(2), 256-265

Holman, B. W. B., & Malau-Aduli, A. E. O. (2013). Spirulina as a livestock supplement and animal feed. *Journal of animal physiology and animal nutrition*, *97*(4), 615-623.

Idenyi, J. N. et al. (2022). Aquaculture sustainability through alternative dietary ingredients: Microalgal value-added products. Engineering Microbiology, 2(4), 100049.

Ishak, K. A. et al. (2017). Nano-delivery systems for nutraceutical application. In Elsevier eBooks (pp. 179–202). https://doi.org/10.1016/b978-0-12-811942-6.00009-1

Janarthanan, M., & Senthil Kumar, M. (2018). The properties of bioactive substances obtained from seaweeds and their applications in textile industries. *Journal of Industrial Textiles*, *48*(1), 361-401.

Kovač, D. J., Simeunović, J. B., Babić, O. B., Mišan, A. Č., & Milovanović, I. L. (2013). Algae in food and feed. Food and Feed Research, 40(1), 21-32.

Lamarque, P., Meyfroidt, P., Nettier, B. and Lavorel, S. (2014) How ecosystem services knowledge and values influence farmers' decision-making. *PLOS ONE,* 9, p. e107572.

Lastra-Bravo, X., Hubbard, C., Garrod, G. and Tolón-Becerra, A. (2015) What drives farmers' participation in EU agri-environmental schemes? Results from a qualitative meta-analysis. *Environmental Science and Policy,* 54, pp. 1-9.

Leimann, L. (2020). Changing behaviours to change the system? Dairy system transformation in Germany (Master dissertation, CAT-Centre for Alternative Technology, UK).

Losada-Lopez, C. et al. (2021). Neophobia and seaweed consumption: Effects on consumer attitude and willingness to consume seaweed. International Journal of Gastronomy and Food Science, 24, 100338.

Lucas, S., Gouin, S., & Lesueur, M. (2019). Seaweed consumption and label preferences in France. Marine Resource Economics, 34(2), 143-162.

Mellor, C. et al. (2022). Consumer knowledge and acceptance of "algae" as a protein alternative: A UK-based qualitative study. Foods, 11(12), 1703.

Mendes, M. C. et al. (2022). Algae as food in Europe: An overview of species diversity and their application. Foods, 11(13), 1871.

Milford, A. et al. (2019). Drivers of meat consumption. Appetite, 141, 104313.

Moldovan, S. et al. (2017). Printing of cotton with eco-friendly, red algal pigment from Gracilaria sp. In *IOP Conference Series: Materials Science and Engineering*, 254(19), 19201. IOP Publishing.

Moss, R., & McSweeney, M. B. (2021). Do consumers want seaweed in their food? A study evaluating emotional responses to foods containing seaweed. Foods, 10(11), 2737.

Mutaf-Kılıç, T. et al. (2023). Microalgae pigments as a sustainable approach to textile dyeing: A critical review. Algal Research, 103291.

Nicoletti, M. (2016). Microalgae nutraceuticals. Foods, 5(3), 54

OECD. (2017). Using behavioural insights to incentivize environmentally sustainable food consumption. In Tackling Environmental Problems with the Help of Behavioural Insights. OECD Publishing. Paris.

Palmieri, N., & Forleo, M. B. (2020). The potential of edible seaweed within the western diet. A segmentation of Italian consumers. International Journal of Gastronomy and Food Science, 20, 100202.

Palmieri, N., & Forleo, M. B. (2022). An explorative study of key factors driving Italian consumers' willingness to eat edible seaweed. Journal of International Food & Agribusiness Marketing, 34(4), 433-455.

Pardilhó, S. (2022). Marine macroalgae in a circular economy context: A comprehensive analysis focused on residual biomass. *Biotechnology Advances,* 107987.

Pulz, O., & Gross, W. (2004). Valuable products from biotechnology of microalgae. *Applied microbiology and biotechnology*, *65*, 635-648.

Redway, M, Parrett, A, and Combet, E (2022) Exploring UK consumers' intake, perceptions, and awareness of seaweed. Proceedings of the Nutrition Society, 81(OCE5), 2022. doi:10.1017/s0029665122002130.

Ribeiro, P. R. et al. (2023). Consumers' Engagement and Perspectives on Sustainable Textile Consumption. Sustainability, 15(22), 15812.

Röös, E., et al. (2017). Greedy or needy? Land use and climate impacts of food in 2050 under different livestock futures. *Global Environmental Change*, *47*, 1-12.

Rouphael, Y., & Colla, G. (2020). Toward a sustainable agriculture through plant biostimulants: From experimental data to practical applications. Agronomy, 10(10), 1461.

Salgado, A. et al. (2023). Chocolates enriched with seaweed: Sensory profiling and consumer segmentation. International Journal of Gastronomy and Food Science, 33, 100747.

Shields, R. J., & Lupatsch, I. (2012). Algae for aquaculture and animal feeds. *J Anim Sci*, *21*(1), 23-37.

Singh, A. et al. (2019). Green cosmetics-Changing young consumer preference and reforming cosmetic industry. International Journal of Recent Technology and Engineering (IJRTE), 8, 12932.

Sondak, C. F., & Chung, I. K. (2015). Potential blue carbon from coastal ecosystems in the Republic of Korea. *Ocean Science Journal*, *50*, 1-8.

Tengli, A., & Srinivasan, S. H. (2022). An exploratory study to identify the gender-based purchase behavior of consumers of natural cosmetics. Cosmetics, 9(5), 101.

Teoh, S. L. et al. (2019). Factors affecting consumers' decisions on the use of nutraceuticals: a systematic review. International journal of food sciences and nutrition, 70(4), 491-512.

Thiyagarasaiyar, K. et al. (2020). Algae metabolites in cosmeceutical: An overview of current applications and challenges. Marine drugs, 18(6), 323.

Ullmann, J., & Grimm, D. (2021). Algae and their potential for a future bioeconomy, landless food production, and the socio-economic impact of an algae industry. Organic Agriculture, 11(2), 261–267.

United Nations. Causes and effects of climate change. Retrieved from https://www.un.org/en/climatechange/science/causes-effects-climate-change.

Vigani, M., Parisi, C., Rodríguez-Cerezo, E., Barbosa, M. J., Sijtsma, L., Ploeg, M., & Enzing, C. (2015). Food and feed products from micro-algae: Market opportunities and challenges for the EU. *Trends in Food Science & Technology*, *42*(1), 81-92.

Weickert, S. et al. (2021). Algae production technology: Effect of framing on German consumer acceptance. Algal Research, 58, 102401.

Weinrich, R., & Elshiewy, O. (2019). Preference and willingness to pay for meat substitutes based on micro-algae. *Appetite*, *142*, 104353.

Wells, M. L. et al. (2017). Algae as nutritional and functional food sources: revisiting our understanding. *Journal of Applied Psychology*, 29, 949-982.

Wendin, K., & Undeland, I. (2020). Seaweed as food–Attitudes and preferences among Swedish consumers. A pilot study. International Journal of Gastronomy and Food Science, 22, 100265.

Young, M, Paul, N, Birch, D, and Swanepoel, L (2022) Factors Influencing the Consumption of Seaweed amongst Young Adults. Foods, 11(19), 1–18. doi:10.3390/foods1119305

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