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The Perception of Consumers about Algae as Alternative Protein Source: A Systematic Literature Review

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I. Abstract

The rapidly increasing global food demand requires us to look at (new) alternative ways of sustainable food consumption and production. Algae (incl. seaweed) has been proven to be a viable source of protein that provides many healthy, nutritional and environmental benefits. In order to successfully introduce algae-based protein products into the market, it is important to know current perceptions are of consumers of algae as an alternative protein source.

A search query resulted in sixteen papers related to the consumer perception of algae that were available for retrieval. The analysis of these papers showed four main approaches on measuring consumer perception of algae: sensory evaluation, consumption motives/barriers, preference, and acceptance.

The results show that algae-based protein products were generally positively perceived and accepted for their healthy and sustainable characteristics. These characteristics were preferred aspects of algal food products. Moreover, healthiness and sustainability were the main motives for algae consumption, whereas food neophobia and lack of knowledge/familiarity formed the main barriers. The influence of sensory aspects (e.g. taste) on the perception of algae was ambiguous as it was rated differently among consumers.

Future research should focus on increasing the reliability of these findings, while also focusing on methods to positively influence the consumer perception of algae and introducing algae to the greater audience.

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1. Introduction

With the rapidly increasing global food demand (Tilman, Balzer, Hill & Belfort, 2011), one of the biggest challenges of today's world is how we can feed the world in 2050 (Le Mouël & Forslund, 2017). We have to be able to produce more food while using less resources than today. This requires new ways of looking at (sustainable) food production. One sector in which this is especially needed is the meat industry. This industry is responsible for high levels of greenhouse-gas and other pollutant emissions and requires too much land and water. With the amount of meat we consume on a global daily basis, it is therefore impossible to reach and retain the sustainable development goals (SDGs) with regard to the environment and climate (Springmann, Sexton, Lynch, Hepburn & Jebb, 2019). As a result, we might have to cut the production of meat globally. However, this is difficult.

In many countries, "meat has a special place in human diets" (Springmann et al., 2019), and although the health benefits of meat are questioned, it is a source of many micronutrients and a great source of protein which are needed for good health (Springmann et al., 2019). We have to look at pathways in which we meet the growing demand of proteins in a sustainable and healthy manner. This can be done in three ways: 1. Alternative proteins, 2. Changes to current production systems and 3. Consumer behaviour change (Springmann et al., 2019). This report will focus on algae as future alternative protein and the perceptions of consumers that are linked to it. It therefore combines the pathway of alternative proteins and consumer behaviour change.

Macroalgae and microalgae are viable sources of protein and some species of it contain protein levels similar to, or even greater than those of traditional plant and animal protein sources (Bleakley & Hayes, 2017). The use of algae for protein production also provides many benefits over traditional protein production systems. For example, in terms of productivity and nutritional value, but also in the use of water in the process, which is much less than in the production of animal and other plant proteins (Bleakley & Hayes, 2017). It therefore seems that algae form a real opportunity for future alternative protein consumption. However, this is where challenges occur. To get people into buying algae-based protein products requires deliberately changing their (food) consumption habits and patterns, which is complicated (Mont & Power, 2010). This process starts with people considering alternative food products, for example algae-based meat substitutes.

To be able to successfully introduce algae-based proteins in the market, it is important to know what consumers think about algae as alternative protein source. This report aims to give a state-of-the-art insight of the perceptions of consumers about algae-based protein sources by researching what is already known in existing scientific literature. The following research question is hereby constructed:

What are the perceptions of consumers about algae as alternative protein sources?

By answering this question, this report hopes to create a clear overview of the current perceptions of consumers about algae-based protein products on which more profound future research can be based upon.

1.2 Theoretical Framework

In order to acquire the information to answer the research question, a theoretical framework is needed to specify the relevant concepts providing this information. This framework, in the end, informs the search terms that will be used in the systematic literature review.

1.2.1 Importance of consumer involvement

Businesses, start-ups and new product developers could have the most innovative and creative ideas, or have the most revolutionary product, or the most attractive and satisfying food, the success of these ideas and products are always dependent on the response and attitude of the consumer (Lesschaeve & Bruwer, 2010). Understanding the problems and needs of the customer is a critical success factor for all market-driven developers (Svendsen, Haugland, Grønhaug & Hammervoll, 2011). Therefore, it is important to involve consumers in the process of developing a new product or service (Svendsen et al., 2011). As a start, this can be done by examining the consumers' perception of new products and ideas.

The way consumers react to (new) food products has shown to be related to the perception of consumers of these food products. This response is influenced by many factors, including attitudes and believes (Šarčević et al., 2011). Therefore, this report will not only include keywords like perception, but also keywords like attitude, reaction, opinion, beliefs and perspective in the configuration of the search term.

1.2.2. Consumer Perception

There are many different theories on how to accurately measure the consumer perception of certain products and services. For this research, the Cue Utilization theory of Olson is selected. According to this theory, consumers assess the quality of products based on a set of

cues. These cues are called upon based on their predictive and confidence values (Richardson, Dick & Jain, 1994). The predictive value of a cue "is the degree to which consumers associate a given cue with product quality", whereas the confidence value of a cue is the degree to which consumers are confident in using and judging this cue in the correct way (Richardson, Dick & Jain, 1994).

The cues can be distinguished into extrinsic cues and intrinsic cues. Extrinsic cues are attributes that are product-related, but that are not part of the part of the physical product. These could be brand, name and packaging for example. Intrinsic cues however, are attributes that are part of the physical product and which cannot be steered without changing the physical product itself (Richardson, Dick & Jain, 1994). In the context of food products, intrinsic attributes could exist out of for example taste, colour, smell, texture, healthiness or appearance (Espejel, Fandos & Flavián, 2007). Evidence suggests that both extrinsic and intrinsic cues have high perceived and confidence values and are both used by consumers in assessing the quality of product (Richardson, Dick & Jain, 1994). The perceived quality of a food product in return determines the food choice and demand of a consumer (Grunert, 2005). However, the market for algae-based protein products is still in development phase due to which specific brands do not yet exist and packaged products are not widely available. Therefore, extrinsic attributes, like brand or packaging, are not essential for this research. Hence, this research will only use intrinsic attributes when constructing the search term (see method).

1.2.3. Algae

When talking about algae, they can be classified in either macroalgae or microalgae (Carlsson, van Beilen, Möller & Clayton, 2007). Macroalgae consist of seaweeds, which are plants that are growing in salt or freshwater. Seaweeds can be divided into three subgroups; brown seaweed (Phaeophyceae), red seaweed (Rhodophyceae) and green seaweed (Chlorophyceae).

Microalgae are microscopic organisms that also grow in salt or freshwater (Carlsson et al., 2007). There are many species of microalgae, but these can also be divided into three important classes; diatoms (Bacillariophyceae), green algae (Chlorophyceae) and golden algae (Chrysophyceae). Cyanobacteria, known as blue-green algae (for example Spirulina), are also considered as microalgae (Carlsson et al., 2007).

Many algae species contain a high amount of nutritional value and protein and are less

stressful on the environment in their production. Therefore, they are a viable alternative for the currently established proteins.

2. Method

To obtain the information about the consumer perception of algae (protein) products, a systematic review of the published literature was conducted. This was performed in SCOPUS. This database offers a great amount of articles and papers out of journals and books with a wide range of topics and is therefore well suitable for acquiring the relevant information related to the aim of this research.

In order to find the publications that are relevant for this research, a search query had to be constructed. With help of the theoretical framework, this term is related to four blocks of keywords. The first block is 'the actor' (1). This block refers to the people, the consumers, whose perceptions we investigate. These perceptions will be measured on the basis of certain 'cues' (2). These cues act as a limit for the fetched papers by including specific keywords related to consumer perception of food. In the end, the goal is to procure information about what consumers think of algae as alternative protein source: 'the evaluation' (3). Following this is the third block: 'the object' (4). As mentioned in the theoretical framework, algae itself is a broad term and can be classified into different sub-forms, which when covered can result in more information about the research question.

At last, the information that is pursued should be up to date. Therefore, a year limit of 2000 – 2020 should be set for the including papers. Moreover, the papers should also be written in English for practical purposes.

Finding the right search query was a process of trial and error. Search terms were adjusted, broadened or limited based on the amount of papers and articles that were found. With aid of the theoretical framework, three promising search queries were constructed. In order to select the final one, the first 10% of the fetched publications provided by these search queries separately, were analysed based on their abstracts. The search query with the best proportion of relevant articles was chosen for the analysis (table 1).

Table 1: Final search query strategy	
Block	**Search term**
Actor	(consum* OR buyer* OR customer* OR user*)
	AND
Cues	(taste OR smell OR colour OR health* OR texture OR appearance OR quality) AND food*
	AND
Evaluation	(percept* OR attitude* OR reaction* OR opinion OR belief* OR notion OR perspective)
	AND
Object	(alga* OR microalga* OR macroalga* OR diatom* OR seaweed OR spiru*)
	AND
Other	Language = (English) And Year = (2000-2020)

The 'OR' works as a Boolean operator that composes a combined set of at least one of the search terms. The 'AND' is also a Boolean operator that makes a set of elements that contain both search terms. The (*) indicates a wild card that can be replaced by any string in a single go. (e.g. consum* covers consumer, consumers, consumption etc.)

The objective is to have a selection of articles and papers in the end that are relevant to answer the research question. To reach this objective, a coding scheme was developed with the main topics:

1. Research (sub) themes (whether it is focused on algae perception or not)
2. Type of research (empirical, non-empirical etc.)
3. Primary variables (dependent and independent)
4. Scope of research (target subjects, number of people investigated and method used)
5. Key findings related to the consumer perception of algae as alternative protein

The final search was conducted on the 17th of March 2020.

3. Results

The search term from table 1 resulted in 127 potential papers. Articles were screened based on their titles and abstracts. This led to the retrieval of 34 papers. The other 93 papers were excluded based on the first rejection criteria. These papers did not fit the theme of this research (see figure 1).
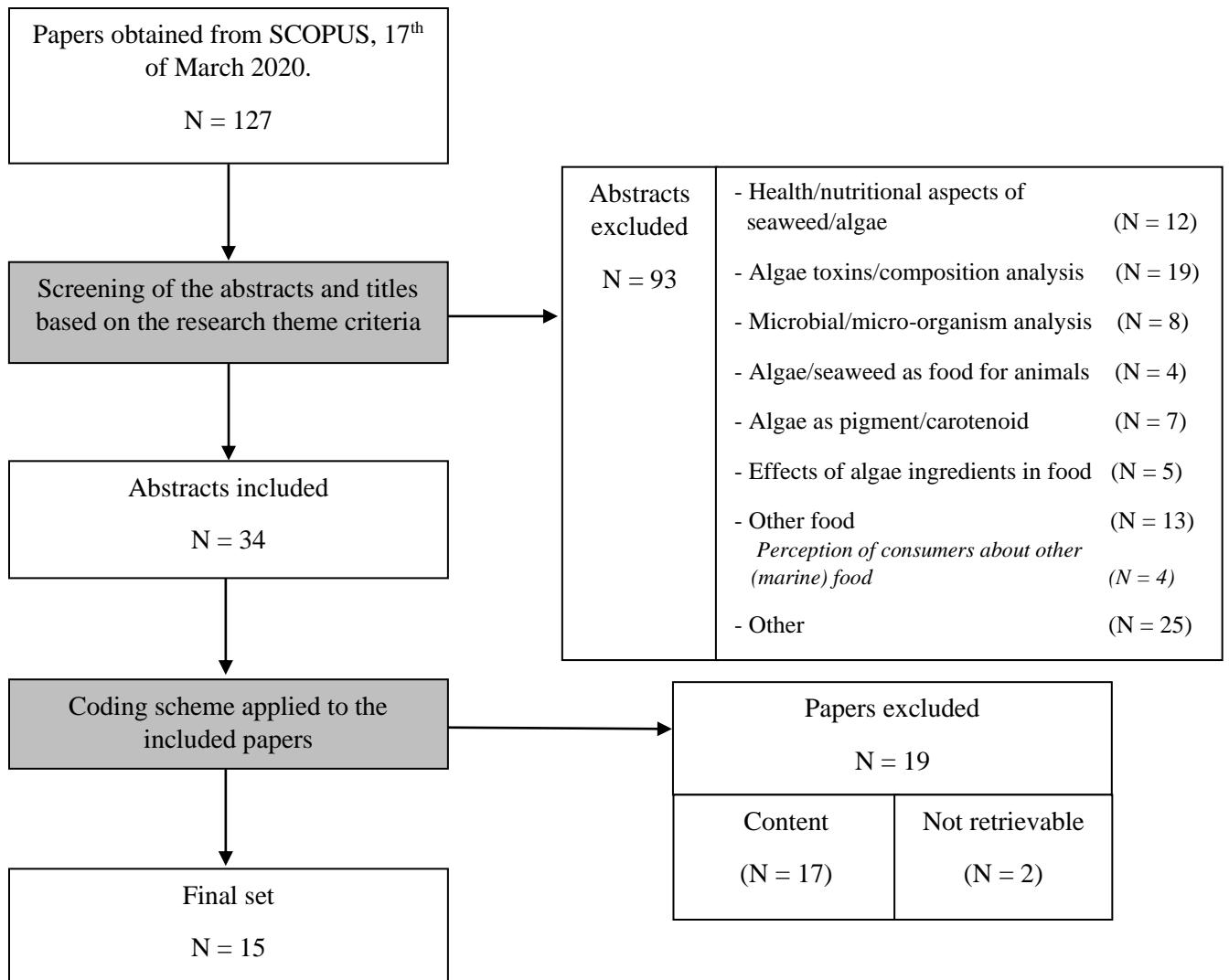

Papers obtained from SCOPUS, 17th of March 2020. N = 127		
Screening of the abstracts and titles based on the research theme criteria	Abstracts excluded N = 93	- Health/nutritional aspects of seaweed/algae (N = 12) - Algae toxins/composition analysis (N = 19) - Microbial/micro-organism analysis (N = 8) - Algae/seaweed as food for animals (N = 4) - Algae as pigment/carotenoid (N = 7) - Effects of algae ingredients in food (N = 5) - Other food (N = 13) *Perception of consumers about other (marine) food* (N = 4) - Other (N = 25)
Abstracts included N = 34		
Coding scheme applied to the included papers	Papers excluded N = 19	
Final set N = 15	Content (N = 17)	Not retrievable (N = 2)

Figure 1: Flowchart of selection process.

Out of these excluded papers, twelve papers covered only the nutritional and health aspects of seaweed and algae. Another nineteen papers analysed the toxicity and composition of algae and had nothing to do with consumer perception. Subsequently, eight papers analysed algae as a microbial/micro-organism substance. There were also four papers that discussed algae as a food source for animals and seven papers that discussed algae as a pigment/carotenoid. Furthermore, another five papers analysed the effect of algae ingredients in several food

products, but none of those papers covered the perception of consumers about these food products. Thirteen papers were focused on researching other marine food rather than algae/seaweed and were therefore excluded from the final set. Four of these papers also included the consumer perception about these foods.

At last, 25 papers could not be clustered because of the complexity of their research themes and/or other papers with comparable themes were not found.

The full text of the 34 included papers was retrieved from the library of Wageningen University & Research. Two of these papers were not retrievable. After a quick read of the full-text of the papers, another seventeen articles were excluded based on the rejection criteria related to the research (sub) themes. In the end, fifteen articles were available for full in-depth analysis.

3.1 Description of the final set of papers
The oldest paper was published in 2005, whereas the newest paper was published in 2020. The papers were published in fourteen different journals. One publication was part of a book. Furthermore, eight of the papers were published in journals that were related to food. The other journals could not be categorized into clusters as they all covered a different theme. The papers were co-authored by 50 different authors.

Out of the fifteen papers, thirteen were reports of empirical research. The data in all these papers were gathered either through surveys, survey experiments and/or qualitative interviews. Two papers were non-empirical reports. One of these papers was a literature review (Pereira, 2011). The other paper, "Microalgae for integrated food and fuel production" by Rösch, Rossmann & Weickert (2018) followed a codesign approach. Information about consumer perception of microalgae based food products in this paper was obtained through prior conducted research by the same authors. This led to the discovery of another paper that was not obtained by the created search term in SCOPUS ('snowball effect'): "Key-Narratives of Microalgae Nutrition" by Rossmann & Rösch (2018). This paper has been added to the final set of papers, bringing it to sixteen. The paper of Rösch, Rossmann & Wieckert (2018) gives a short summary of the key findings about the consumer perception of microalgae in the paper of Rossmann & Rösch (2018).

The data in the empirical papers were collected in eleven different countries, most of them European: USA (2), Germany (4), Turkey (1), Norway (1), Canada (1), Poland (1), The Netherlands (2), France (3), Kingdom of Bahrain (1), Australia (1) and Italy (1). With four

papers, Germany is the purveyor of data to the court. There were two papers that provided information about consumer perception of algae proteins of three different countries: "Preference and willingness to pay for meat substitutes based on micro-algae" by Weinrich & Elshiewy (2019) and "Consumer-Oriented Product Development: The Conceptualization of Novel Food Products Based on Spirulina (Arthrospira platensis) and Resulting Consumer Expectations" by Grahl, Strack, Weinrich and Mörlein (2018). The authors conducted consumer surveys in Germany, France and The Netherlands.

3.2 Primary variables

An analysis of the fourteen empirical papers (including the paper of Rossmann & Rösch (2018)) provided some useful insights. Differences and similarities can be observed when looking at the independent and dependent variables of the reports. All these papers research the perception of study participants about algae/seaweed, but there are some aspects in these papers that could be distinguished from one another.

First of all, the independent variables are not the same in all the studies. The independent variables existed either of (edible) unprocessed types of seaweed/algae or about food products containing seaweed/algal ingredients. Four papers measured the perception of study participants specifically about edible seaweed and algae, whereas six papers measured the perception of participants about food products containing seaweed/algal ingredients. Two papers did a cross-over study and measured both. One study stood out as it exclusively looked at microalgae as functional ingredient for supplements (Rzymski & Jasckiewicz, 2017). The perception of these supplements was measured among Polish consumers.

Considering the different types of algae, there were three papers that measured the perception of the participants specifically about seaweed. Two papers measured the perception of spirulina as a food ingredient and six papers measured the perception of algae species. Two papers were about algal oil extracts as a food ingredient and one paper was about agar (algae extract) as a sugar-replacing substance in fruit jellies (Riedel, Böhme & Rohm). Three papers had a combination of these independent variables.

Lastly, two papers specifically looked at seaweed and algae as potential dietary food replacing protein source (Lucas, Gouin & Leasueur, 2019 and Weinrich & Elshiewy, 2019).

When looking at the dependent variables, some similarities and differences could be observed too. There were eight papers that specifically measured the preference of study participants when facing certain types of seaweed and algae and/or types of food products/dishes containing algal ingredients. One of these papers specifically measured the label preferences

regarding seaweed products (Lucas, Gouin & Lesueur, 2019). Five papers measured the perception of sensory attributes, like taste, of seaweed/algae. Seven papers also measured the motivations of the study participants why to consume or to not consume seaweed and algal food products.

At last, no less than eleven papers measured the acceptability of algae and seaweed of consumers as an alternative food source/ingredient.

An overview of the primary variables of the fourteen empirical papers can be seen in table 2 (appendix 1).

3.3 Scope of research

Some useful insights can be observed in the scope of research of the empirical papers. The scope of research is concerned with the research method used, the target subjects and the number of study participants of the papers.

The research methods can be classified in panels, surveys/questionnaires, interviews and experiments. Consumer surveys were the most used method of all the papers (N = 9), followed by panels (N=4). These panels could be distinguished in a trained panel, an untrained panel or a combination of both. The paper "Evaluation of the Cooking Quality Characteristics of Pasta Enriched with Spirulina Platensis" by Özyurt et al. (2015) was the single paper that made use of only a trained panel. The paper of Riedel, Böhme & Rohm "Development of formulations for reduced-sugar and sugar-free agar-based fruit jellies" was the only paper that made use of an untrained panel, who received little to no information about the fruit jellies that they were tasting. Two papers made use of both a trained panel and an untrained panel (Chee et al., 2005 & Chapman, Stévant & Larssen, 2015) The untrained panels of these papers existed of a consumer panel and were supplemented with a survey. In the paper of Chapman, Stévant & Larssen (2015, the trained panel had to evaluate different species of seaweed, whereas an untrained consumer panel was used to measure the perception of fish cakes containing brown sugar kelp. The paper of Chee et al. (2005) measured the sensory perception of strawberry flavoured yogurt supplemented with an algae oil emulsion. The trained panel was trained to distinguish fishy off-flavours in food products whereas the untrained panel did not receive any information of the yogurt they were about to taste. The results of this study show that there is a difference in the sensory perception between the two panels. The trained panel could distinguish a fishy off-flavour of the yogurt while the untrained panel did not notice any difference and evaluated both the yogurt with and without an algae oil emulsion as 'moderately liked' (Chee et a., 2005).

There is one paper that conducted experiments (Al-Thawadi, 2018) in which participants needed to taste algae (products). As an addition, this paper also conducted a consumer survey. The paper of Rapinski, Cuerrier, Harris & Lemire "Inuit Perception of Marine Organisms: From Folk Classification to Food Harvest" (2018) was the only paper that conducted qualitative interviews.

No significant differences were found in the target subjects of the fourteen empirical papers. Most of these studies aimed to investigate the perceptions of consumers of the country of origin of the authors, with no particular aim for an age category. There were three papers which form an exception; the papers of Grahl et al. (2018) and Weinrich & Elshiewy (2019), that aim to investigate the perception of consumers of three different countries (Germany, France and The Netherlands), and the paper of Rapinski et al. (2018), that specifically investigate the Inuit community in Canada. A sidenote could also be made for the papers of Chee et al. (2005) Riedel, Böhme & Rohm (2015) and Al-Thawadi (2018). Although these papers did not particularly target a specific consumer group, their study participants did exist of mostly students and for the latter paper also males. The study participants in the paper of Rzymski & Jaśkiewicz (2017) existed of mostly females.

Looking at the number of study participants, most papers have a fair amount of respondents. The number respondents of the papers that conducted surveys ranges from 150 to 1035. The number of participants in the papers that (also) made use of panels ranges from 7 to 239. Rapinski et al. (2018) gathered data by conducting twelve interviews with fifteen elders from an Inuit community living in the region of Nunavik (Canada).
Al-Thawadi (2018) was able to engage a total of 1030 participants in his two experiments. An overview of the methods used, target subjects and number of participants/respondents can be seen in table 3 (appendix 1).

3.4 Key findings

The key findings of the final set of papers provide the insights into the consumer perception of algae as an alternative protein source. Beside the valuable insights into consumer perception aspects of algae, the analysis also provides valuable insights into general motives of researching algae as (future) food source.

The importance of exploring algae as alternative food source
As mentioned in the introduction, algae is viable source of protein that provides great nutritional value and many health and environmental benefits. When analysing the papers,

these aspects served as an incentive for almost every paper to further explore the implementation of algae as a food source. The health and nutritional value that algae is able to provide has been cited by no less than twelve papers. Weinrich & Elshiewy (2019) for example mentioned that micro-algae based meat substitutes can be considered as healthful due to their favourable, high quality, nutritional protein value, whereas Birch, Skallerud & Paul (2019) mentioned that seaweed is a "functional food that is highly nutritious, rich in antioxidants and fibre, and contain beneficial micronutrients". Moreover, it provides "various health benefits, including improved digestive track and bone health, and prevention of chronic conditions and diseases" (Birch, Skallerud & Paul, 2019).

The environmental benefits of algae has been cited by five papers. Weinrich & Elshiewy (2019) mentioned that microalgae can be produced on non-arable land and allows for a high production rate per square meter (Weinrich & Elshiewy, 2019), whereas the sustainability benefits of spirulina are associated with the potential of localized production using marginal amounts of land (Grahl et al., 2018). Furthermore, sustainability is an interesting attribute of seaweed (Lucas, Gouin & Lesueur, 2019) and therefore a good alternative for meat production (Birch, Skallerud & Paul, 2019). The consumption of seaweed is able to unite both nutritional and environmental goals (Palmieri & Forleo, 2020).

The health and environmental benefits of algae provide incentives to further explore the implementation of algae-based foods/proteins in society.

Sensory aspects

Of the sixteen included papers, six papers measured the sensory perception of consumers about algae and/or seaweed. Five of these papers let study participants taste algae/seaweed in an experiment, either in edible unprocessed form or processed as an ingredient in a food product. One paper asked for sensory evaluation based on prior seaweed consumption (Birch, Skallerud & Paul, 2019). Sensory characteristics were mainly focused on taste in these papers. In overall, the evaluation of sensory attributes were quite mixed. In two papers, sensory attributes were positively evaluated (Özyurt et al., 2015 & Al-Thawadi, 2018). In the paper of Al-Thawadi (2018), sensory appeal even has a positive indirect impact on the behavioural intention of people to consume algal products.

In one paper, sensory attributes were evaluated negatively (Birch, Skallerud & Paul, 2019). In this paper, dislike of smell, taste and texture were mentioned as reasons to not consume seaweed by respectively 39%, 37% and 33% of the respondents.

In the other three papers (Chee et al., 2005 & Riedel, Böhme & Rohm, 2015 & Chapman,

Stévant & Larssen, 2015), the sensory attributes of algae were evaluated in comparison with control products without algae as an ingredient. Both the algal products as the control products were evaluated similarly by the consumers. No real preferences were observed in these papers.

Consumption motives

As mentioned before, there were seven empirical papers that measured the motives of consumers to consume or not consume algal products. In addition, the two non-empirical papers (Pereira, 2011 & Rösch, Rossmann & Weickert, 2018) also mention algae consumption motives. In these papers, health and nutrition benefits were mentioned no less than eight times to be important motivations for people to consume algae. Birch, Skallerud & Paul (2019) for example mentioned that health and nutritional benefits were key drivers for Australian consumers to consume seaweed.

Sustainability and environmental benefits of algae/seaweed have been mentioned by five papers to have a positive influence on the consumption of algae. Rösch, Rossmann & Weickert (2018) mentioned that consumer awareness of sustainability (but also health) could have a positive influence on the willingness to buy algae products.

Beside positive consumption motives, there are also reasons that form barriers for people to consume algae/seaweed.

First, neophobia seems to be the main barrier of consumers to buy algal products (mentioned in three papers). Linked to this is the lack of knowledge/familiarity (mentioned in four papers as a barrier). However, presence of knowledge/familiarity can also have a positive influence on the consumption of algae, as is mentioned in the papers of Lucas, Gouin & Lesueur (2019) and Al-Thawadi (2018).

Furthermore, lack of availability, affordability and concerns about health risks have also been mentioned as barriers for algae consumption.

The influence of seaweed characteristics (for example taste, texture, appearance etc.) on the consumption motives of algae is relatively unclear. While in some papers, these characteristics are positively evaluated (e.g. Al-Thawadi 2018), there are also papers in which characteristics like taste and texture have a negative influence on the willingness to consume algal products (Lucas, Gouin & Lesueur, 2019 & Birch, Skallerud & Paul, 2019).

Consumer preferences

The analysis of the papers revealed specific preferences of consumers regarding algal foods. Grahl et al. (2018) found that spirulina in combination with pasta was preferred over other

food products. They also found that healthy spirulina was preferred over sustainable spirulina. Following this, a trained panel in the paper of Özyurt et al. (2015) found that a 10% share of spirulina in pasta dishes is preferred over 5% and 15%. Respondents in the study of Weinrich & Elshiewy (2019) preferred egg as the main second ingredient in meat substitutes based on microalgae. Peas was second preferred second ingredient. Soy was the least preferred second ingredient. This study also observed a preference for organic (64%) and locally produced (79%) microalgae based meat substitutes by consumers. Notably, communicating the positive environmental effects of microalgae also increases consumer preference (Weinrich & Elshiewy, 2019). This in line with the research of Rossmann & Rösch (2018), who observed that climate benefits were the most desired aspects of microalgae, followed by world hunger benefits. No preference for share of microalgae in meat substitutes was found by Weinrich & Elshiewy (2019).

Lucas, Gouin & Lesueur (2019) measured the preference of consumers of several seaweed product labels. Results in this study show that environmental and health labels were most preferred by consumers (with environmental labels having slightly higher preference over health labels). Environmental labels however, do not provide any additional value to consumers when seaweed is bought in organic shops.

Acceptance of algae

Eleven papers measured in several ways the overall acceptance of study participants of algae and seaweed. Six of these papers measured the acceptance specifically of algae as food ingredients. Chee et al. (2005) for example measured acceptance of strawberry flavoured yogurt with an algae oil emulsion. Although this yogurt was rejected by a trained panel for its fishy off-flavour, a consumer panel did accept it. Grahl et al. (2018) measured the acceptance of spirulina as an ingredient in a few food products (pasta, sushi and jerky). Spirulina as an ingredient for pasta was accepted by the consumers, while sushi and jerky received a more or less a neutral score. The panel in the paper of Özyurt et al. (2015) also accepted spirulina as a pasta ingredient. Riedel, Böhme & Rohm (2015) discovered that agar-based sugar-free fruit jellies were also accepted nicely by consumers provided they did not know it was sugar-free. Furthermore, brown algal sugar kelp (saccharrina latissima) was found to be accepted in fish cakes by consumers in Norway. Moreover, the use of seaweed as an ingredient for food dishes was also accepted by chefs in Norway (Chapman, Stévant & Larssen, 2015).

There was one paper in which algae had a low acceptance score by consumers as an ingredient in milk, bread and supplements (Cox, Evans & Lease, 2010).

The remaining five papers measured the overall acceptance of algae/seaweed on several variables, for example sensory aspects, consumption motives/barriers and preferences. In short, algae and seaweed were found to be accepted by consumers based on these variables. Particularly interesting for this research is that the acceptance of microalgae based meat substitutes seemingly is driven by consumer attitudes that is targeted at the unhealthfulness and unethicality of meat (production) (Weinrich & Elshiewy, 2019). Any negative attitudes towards algae/seaweed (like mentioned in the consumption motives) are generally valued lower than positive attitudes, as is the case in for example the paper of Birch, Skallerud & Paul (2019).

Three papers mentioned that communicating health and nutritional benefits of algae/seaweed increases consumer acceptance (Al-Thawadi, 2018, Weinrich & Elshiewy, 2019, Palmieri & Forleo, 2020).

Differences in countries and demographics
No relevant differences were found in the papers in the perception of consumers about algae/seaweed between the examined countries. Notably, seven papers mentioned the habit of Asian cultures to consume algae and seaweed products. According to Al-Thawadi (2018), algae are considered to be a main food source of Asian people, whereas seaweed is also a major element in the human diets in Asian countries (Chapman, Stévant & Larssen, 2015). Asian cultures highly value algae and seaweeds for their appearance, texture, flavour and health benefits. These attitudes are different from people in Western countries (Pereira, 2011), where people are more careful in the judgement of algae and seaweed because of lack of knowledge and familiarity. However, due to globalisation, American and European citizens are more exposed to food habits from other countries and cultures, which increases the acceptance of algae and seaweeds of these people (Al-Thawadi, 2018).

In most empirical papers, there were no significant differences found in the perception of algae/seaweed between people with different demographic aspects. Two papers however did notice some differences. Palmieri & Forleo (2020) observed that people with a lower level of education are generally more unfamiliar and have less knowledge about the consumption of seaweed than people with higher levels of education. This in return negatively influences the willingness to consume seaweed. Birch, Skallerud & Paul observed (2019) similar differences. Their study found that people with higher levels of education were more willing to consume seaweed as well. They also noticed that household incomes, gender and age were factors that influenced the willingness to consume. Younger consumers, females and people

with higher household incomes were more willing to consume seaweed (Birch, Skallerud &
Paul, 2019).

A summary with the key findings of the papers can be found in table 4 below.

Table 4: Key findings of final set of papers

Paper	Key findings
1. The potential of edible seaweed within the western diet. A segmentation of Italian consumers (Palmieri & Forleo, 2020)	- "Results show that 76% of the people were willing to eat seaweed", possibly "due to familiarity with some traditional Italian dishes using seaweed ingredients or due to the spread of Asian gastronomy in Italy". "This number may indicate that people are becoming more receptive to novel foods, especially the ones that provide health and sustainable benefits" - Results show that 57% have eaten seaweeds before. - The respondents have been divided into seven clusters. In five out of the seven clusters (ranging in conception levels), consumers consistently paid attention to health characteristics of food. - For some clusters, seaweed characteristics and availability were also important factors for influencing consumer attitudes. - Neophobia can affect people in consuming seaweed. - In general, consumer perceptions of edible seaweed were quite positive.
2. Preference and willingness to pay for meat substitutes based on micro-algae (Weinrich & Elshiewy, 2019)	- Results show that the most preferred second ingredient of a microalgae based meat substitute is egg, followed by peas and milk. Soy is the least preferred second ingredient. - Results show that consumers prefer microalgae based meat substitutes that organic and local (64%, 79%). - Communicating the environmental friendly food production of microalgae based meat substitutes compared to meat increases consumer preference. - There is no preference of share of microalgae within the food product. - No significant differences were found between countries.

	- Consumers with a negative attitude towards the healthiness of meat and ethicality of meat production have a higher acceptance of microalgae based meat substitutes. - Consumers with a strong habit for meat consumption show a lower preference for choosing microalgae based meat substitutes.
3. Seaweed consumption and label preferences in France (Lucas, Gouin & Lesueur, 2019)	- Based on the results, the respondents can be distinguished in three groups of seaweed consumers: 1. Consumer group J, which are people that only consume Asian seaweed products. 2. Consumer group A, which are people that consume all types of seaweed products. 3. Non-consumers - Consumers group J are more concerned with the dietary attributes of seaweed and have no particular label preference - Consumer group A is positively influenced by peers that already consume seaweed and prior knowledge about seaweed but negatively influenced by price, taste and dietary attributes. - Consumer group A is concerned with health and environmental benefits of seaweed and give more value to environmental labels, and to a lesser extent health labels (but no major difference compared to other groups) - In overall, it has been observed that eco and quality labels are not of importance in organic shops. Health labels on the other hand are important despite the location of consumption.
4. Who Eats Seaweed? An Australian Perspective (Birch, Skallerud & Paul, 2019)	- Results show that people with higher household incomes and higher levels of education are more likely to consume seaweed. Females are also more likely to consume seaweed opposed to men.

		- Results show that health and nutritional benefits are the most important reason of Australian consumers for consuming seaweed. Following this are the environmental and sustainability benefits of seaweed. Symbolic value is also an important factor. - In general, people who are more mindful about their food choices are more likely to consume seaweed. - Australian consumers do not appear to be too concerned about the safety issues of seaweed. - The major obstacle for not consuming seaweed is neophobia (lack of knowledge and familiarity), followed by lack of availability and affordability. Sensory characteristics were also mentioned (dislike of taste and texture). - Potential reasons for not consuming seaweed however were valued lower than reasons for consuming seaweed.
5.	Inuit Perception of Marine Organisms: From Folk Classification to Food Harvest (Rapinski, Cuerrier, Harris & Lemire, 2018)	- This study discusses the marine organisms that are consumed and harvested in the Inuit culture. Algae and seaweed are part of these organisms. - The Inuit community perceives the consumption of marine organisms like algae as a concept of health and wellbeing. - It is consumed because it provides many health benefits. - The high accessibility of algae promotes the consumption of algae.
6.	Consumer-Oriented Product Development: The Conceptualization of Novel Food Products Based on Spirulina (Arthrospira platensis) and Resulting Consumer Expectations (Grahl, Strack, Weinrich & Mörlein, 2018)	- Results show that spirulina is more relevant as a food ingredient for French consumers opposed to German and Dutch consumers. Probably because French consumers had more knowledge about microalgae prior to the questionnaire than the Dutch and German consumers. - Regarding overall liking, pasta with spirulina was preferred over sushi (with spirulina) and jerky. - Healthy spirulina is preferred over sustainable spirulina. - Familiarity with the product category seems to be a mediator in the overall liking of spirulina products.
7.	Public perception of algal consumption as alternative food in the Kingdom of Bahrain (Al-Thawadi, 2018)	- Results show that the consumers in the Kingdom of Bahrain are willing to consume algae.

	- Sensory aspects, perceived healthiness and knowledge/familiarity have a significant positive relationship to perceived risk and uncertainty. These elements have an indirect relationship with behavioural intention to consume products based on algae. - Subjective norm, perceived risk and uncertainty and neophobia directly influence the behavioural intention to consume algae of the consumer.
8. Key-Narratives of Microalgae Nutrition (Rossmann & Rösch, 2018)	- Results show that 47% of the participants had never heard of microalgal food products before. - Looking at the desired aspects of microalgae nutrition in the eyes of the consumer, climate benefits and world hunger prevention seem to be most important aspects. Following this is the opportunity of microalgae to be produced locally. - Taste seemed to be of minor importance. - Three key narratives of microalgae that are expected by consumers has been identified other than sustainably feeding the world. These are 1) microalgae for health and wellness, 2) microalgae for cheap and discrete products and 3) microalgae for decentral and autonomous supply.
9. Microalgal food supplements from the perspective of Polish consumers: patterns of use, adverse events, and beneficial effects (Rzymski & Jaśkiewicz, 2017)	- Results show that spirulina was the most used microalgal supplement. - Most important purpose of consuming microalgal supplements were supporting the immune function (60.7%), providing nutrients (63.3%) and detoxication (50%). Well-being was also mentioned. - Spirulina and chlorella supplements provided the most positive outcomes according to the participants. - Most of the consumers of these supplements were satisfied with the product. Consumers of aphanizomenon based supplements did not observe any beneficial effects and were not satisfied with the product.
10. Development of formulations for reduced-sugar and sugar-free agar-based fruit jellies (Riedel, Böhme & Rohm, 2015)	- The first panel, who had no information, did hardly notice any differences between the sugary fruit jellies and the sugar-free agar based fruit jellies. Therefore, preferences

	were the same for the sugary fruit jellies and the sugar-free agar based fruit jellies. - The second panel, who had information that one sample was sugar-free, preferred the sugary fruit jellies over the sugar-free agar based fruit jellies. Possibly due to negative attitudes towards artificial sweeteners. - Just-about-right (JAR) test showed that the consumers accepted the sugar-free agar based fruit jellies.
11. Evaluation of the Cooking Quality Characteristics of Pasta Enriched with Spirulina Platensis (Özyurt et al., 2015)	- Results show that the pasta with 10% spirulina gives a favourable green tone and provides the best score on flavour and appearance by the panellists. - In overall, all pastas received good scores.
12. Food or fad? Challenges and opportunities for including seaweeds in a Nordic diet (Chapman, Stévant & larssen, 2015)	- "Fish cakes with and without brown algal sugar kelp were equally attractive to consumers with regard to both flavour and appearance". - The preference for one of the two types of fish cakes were both equal and 22% could detect no difference. - Red seaweed has a different sensory profile than kelp species, characterised by the stronger umami flavour. - Palmaria palmata appeared less chewy and crispy than other seaweeds. - Brown algal sugar kelp was preferred in dried desserts by the chefs. - Whether seaweed was steamed or dried did not influence the sensory perception of the seaweeds.
13. The influence of product attributes, consumer attitudes and characteristics on the acceptance of: (1) Novel bread and milk, dietary supplements and (2) fish and novel meats as dietary vehicles of long chain omega 3 fatty acids (Cox, Evans & Lease, 2011)	- Results show that algal oil was the least preferred oil by the consumers as an ingredient for food products. - Novel oilseed was the most preferred oil ingredient.
14. Chemical and sensory analysis of strawberry flavoured yogurt supplemented with an algae oil emulsion (Chee et al., 2005)	- Results show that the yogurt with an algae oil emulsion was less liked than the yogurt without this emulsion by the trained panel. This because of the notable fishy flavour of the yogurt with an algae oil emulsion.

	- The consumer panel could not detect differences between the two yogurts and rated both yogurts equally as 'moderately liked'.
Non-empirical papers	
15. Microalgae for integrated food & fuel production (Rösch, Rossmann & Weickert, 2018)	-The objective of this research is to obtain information about public perception and the views, knowledge and values and stakeholders of microalgae food and fuel production - This paper gives a short summary of the results of the paper of Rossmann & Rösch (2018). Tackling climate change and world hunger, as well as integrating local food supply into other production cycles seem to be the most desired aspects of microalgae. - Consumer awareness of health and sustainability could positively influence the attractiveness of algae products and also positively influence the willingness to buy these products.
16. A review of the nutrient composition of selected edible seaweeds (Pereira, 2011)	- The objective of this research is to describe key nutritional characteristics of the main algae used as human food. - It has been mentioned that Asian cultures highly value seaweeds for their appearance, texture, flavour and health benefits.

4. Discussion

The growing global food demand increases the need to look at new sustainable alternatives in the production and consumption of food. Algae (incl. seaweed) has been proven to be a viable source of protein with many sustainable and nutritional benefits. It is therefore well suitable to be such an alternative. However, before introducing new algae-based food products in the market, it is important to know *what are the perceptions of consumers about algae as (new) alternative protein sources?*

This paper aimed to analyse and review existing studies related to this topic. With the help of a search query, sixteen relevant papers were retrieved in SCOPUS, of which fourteen were empirical.

The data in the empirical papers were mostly collected in western countries. An explanation for this is that the search query only included papers since the year 2000 that were written in English. Relevant research in other countries could be left out of the retrieved set of papers based on these restrictions. Moreover, attitudes of western consumers about algae and seaweed are unrecognized in comparison with e.g. Asian cultures and are therefore worthy to explore.

The analysis of the papers showed four main approaches on measuring consumer perception: sensory evaluation, consumption motives/barriers, preference, and acceptance.
Sensory aspects like taste, texture and appearance were evaluated variously. While for some consumers, the sensory appeal of algae and seaweed has a positive influence on their perception, other consumer were not influenced or negatively influenced by these characteristics. More research is needed to determine the definite effects of sensory aspects on the consumer perception of algae and seaweed.

Perceived health and nutritional benefits are the most important motivations for people to consume algal products. Sustainability and environmental benefits also have a major role in the willingness to consume algae and seaweed. Beside motivations, there are also reasons for consumers that form barriers to consume algal products. Neophobia and lack of knowledge/familiarity are the main barriers for people to consume algae and seaweed. However, this barrier can be taken away if people get more exposed to algal food consumption (e.g. due to globalisation). This effect can be explained by the theory of planned behaviour by Azjen, (1991). According to this theory, the behaviour of people is determined by their intentions to perform the behaviour. These intentions are influenced by attitudes,

subjective norm and perceived behavioural control (Azjen, 1991). Especially subjective norm and intention is of relevance in this case. According to Ham, Jeger & Ivković (2015), subjective norm is concerned with the belief that a group of people will approve and support a particular behaviour. Western people could be exposed to food habits, like algae and seaweed, from other countries and cultures (e.g. Asian), which decreases food neophobia and increases knowledge and familiarity of these foods. This in return increases the acceptance of algae and seaweed and has a positive influence on the intention to buy these kinds of products. This effect has been found in other studies as well. Ting, de Run, Cheah & Chuah (2016) for example found that food neophobia has an moderating effect in the relation between subjective norm and consumption intention.

Regarding preferences of consumers, many people give value to environmental aspects of algal products. This manifests itself in preferences related to product labels and also organic and locally produced production. Health is also an important desired aspect of algal products. One study that is particular interesting is the study of Weinrich & Elshiewy (2019). They measured the preferences of consumers regarding microalgae based meat substitutes, a direct protein alternative. One of these preferences of consumers is to have egg as a second ingredient for meat substitutes based on microalgae, followed by milk. Soy was the least preferred second ingredient. These are interesting findings that may be valuable to new product development (NPD) departments of companies focused on the production of meat substitutes.

Weinrich & Elshiewy (2019) also discovered that the acceptance of meat substitutes based on microalgae is seemingly driven by consumer attitudes that are targeted at the unhealthfulness and unethicality of meat production and consumption. Also, people with a strong habit for meat consumption are less likely to accept and buy microalgae based meat substitutes. This, and also the preferences regarding second ingredients, requires more research in order to determine the reliability of these findings.
In general, algae, whether processed as an ingredient in food products/dishes or raw (edible), was accepted by consumers in almost all of the papers. Communicating health and nutritional benefits, as well as positive environmental aspects may increase the acceptance of algae and seaweed. Future research can be focused upon methods like these to positively influence the acceptance and perception of consumers.

No major differences were found in the perception of consumers between western countries. Only Grahl et al. (2018) found that French consumers had more knowledge about microalgae

than German and Dutch consumers. More research is needed however to justify this statement. Regarding demographic aspects, no significant differences in the perception were found either in most of the papers. Birch, Skallerud & Paul (2019) and Palmieri & Forleo (2020) were the only ones that observed differences in attitudes regarding algae and seaweed. People with lower levels of education were generally more unfamiliar with the consumption of seaweed and are less likely to consume seaweed than people with higher levels of education. Furthermore, Birch, Skallerud & Paul (2019) also observed that household incomes, gender and age were factors that influenced the willingness to consume. Though, more research about this subject needs to be done in order to draw reliable conclusions.

Limitations

Although this review provides valuable insights in known perceptions of consumer about algae and seaweed, there are some limitations of this study.

First of all, this systematic review only made use of one literature database, SCOPUS. Although SCOPUS offers papers with a wide range of topics, it does not include reports, theses and working papers in their database. There might be other databases that provide more papers related to the topic of this research, or these databases might include papers that have not been found by SCOPUS (e.g. reports, working papers).

Second, while the subject of this report is to investigate the current perceptions of consumers about algae as alternative protein source, not all papers that were analysed investigated the perception of consumers about algae for its high protein and nutritional value. These were the papers of Chee et al. (2005), Cox, Evans & Lease (2010) and Riedel, Böhme & Rohm (2015). These papers investigated the consumer response to products containing algal extracts (like algal oil). These extracts are not necessarily meant to be an alternative source of protein or nutrition to these products. Although findings of these papers are still of relevance for this review, they should be considered as offering additional information to the general overview of consumer perceptions about algae.

Another limitation is that there was one paper (Özyurt et al., 2015) included in the final set that gathered their data only by means of a trained sensory panel. A trained sensory panel usually consists of members that are trained to notice subtle differences in the taste (sweetness, saltiness), texture and appearance of certain food products. For this reason, the findings of these paper might not be representative of the whole consumer group, as the average consumer is not able to notice these subtle differences. Moreover, the panel only

consisted of seven members, which is a small amount. This might influence the reliability of the paper as well.

Furthermore, many papers investigated the perception of consumers of algae/seaweed processed in a food product or meal. This results in the fact that algae and seaweed attributes are not evaluated separately, but in proportion to other food products and dishes. This can lead to certain biases. For example, in the paper of Chapman, Stévant & Larssen (2015), consumers were asked to evaluate fish cakes containing brown algae. There might be consumers that are not fond of fish cakes. This may influence the way they evaluate algae. Future studies should do more research on the consumer perception of raw edible types of algae and seaweed.

At last, there are many types of algae and seaweeds which are available for consumption. In the final set of papers, the consumer perception of many different species of algae and seaweed are investigated. Sometimes, it is even unclear which type of algae and/or seaweed is evaluated. While the results adequately outline what is currently known about the perception of consumers about algae nutrition, more research is needed on perceptions of certain types of algae and seaweed in order to acquire information that is useful for following product development.

In the end, this review shows that algae-based protein products are positively perceived and accepted for its healthy and sustainable characteristics. However, neophobia and lack of knowledge/familiarity negatively influences the acceptance of algae and seaweed.
This review can be used as a helpful tool in more profound future research and in the development of new products.

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6. Appendix

Appendix 1: Tables

Table 2: Independent & dependent variables of the empirical papers

Paper	Independent variables*	Dependent variables*
1. The potential of edible seaweed within the western diet. A segmentation of Italian consumers (Palmieri & Forleo, 2020)	Edible seaweed	Preferences and attitudes towards food choice and perceptions and attitudes towards edible seaweed of the study participants. These include willingness to eat seaweed, familiarity, previous consumptions and motivations for consuming seaweed.
2. Preference and willingness to pay for meat substitutes based on micro-algae (Weinrich & Elshiewy, 2019)	Different micro-algae based meat substitute products. Manipulated in: different shares of microalgae, different second ingredients, organic/local or not, amount of less environmental impact and price	Preference of the study participants of microalgae based meat substitutes and attitude towards meat and meat substitutes
3. Seaweed consumption and label preferences in France (Lucas, Gouin & Lesueur, 2019)	Edible seaweed, seaweed products and different seaweed product labels	1. Motivations of meat & fish food consumption habits of the study participants 2. Reasons for consuming or not consuming seaweed based products 3. Seaweed knowledge of the study participants 4. Label preference regarding seaweed products

4.	Who Eats Seaweed? An Australian Perspective (Birch, Skallerud & Paul, 2019)	Edible seaweed and seaweed products	1. Seaweed consumption patterns and dietary preferences of the study participants. 2. Constructs and reasons for consuming or not consuming seaweed
5.	Inuit Perception of Marine Organisms: From Folk Classification to Food Harvest (Rapinski, Cuerrier, Harris & Lemire, 2018)	Different marine food including seaweed and algae	Inuit perception of health and wellbeing
6.	Consumer-Oriented Product Development: The Conceptualization of Novel Food Products Based on Spirulina (Arthrospira platensis) and Resulting Consumer Expectations (Grahl, Strack, Weinrich & Mörlein, 2018)	Three products based on spirulina: filled pasta, sushi and jerky	Preference and acceptability of the products driven by novelty, interest, overall liking, knowledge and taste
7.	Public perception of algal consumption as alternative food in the Kingdom of Bahrain (Al-Thawadi, 2018)	Different types of algae (incl. seaweed and spirulina)	The perceived taste of the participants, the factors contributing to behavioural intention to buy, and the acceptance of the participants
8.	Key-Narratives of Microalgae Nutrition (Rossmann & Rösch, 2018)	Microalgae	The knowledge of microalgae and the desired aspects of microalgae nutrition of the study participants
9.	Microalgal food supplements from the perspective of Polish consumers: patterns of use, adverse events, and beneficial effects (Rzymski & Jaśkiewicz, 2017)	Type of microalgal supplement	Purpose of consuming microalgal food supplements and perceived benefits and satisfaction of these supplements by the participants

10. Development of formulations for reduced-sugar and sugar-free agar-based fruit jellies (Riedel, Böhme & Rohm, 2015)	Different fruit jellies: Sugar containing, sugar-reduced or sugar-free agar-based	The preference of the study participants for the different fruit jellies and the acceptance of sugar-free agar (algae extract) based fruit jellies.
11. Evaluation of the Cooking Quality Characteristics of Pasta Enriched with Spirulina Platensis (Özyurt et al., 2015)	Three pasta dishes with a different amount of spirulina (5%, 10% and 15%)	Evaluation of flavour, appearance, texture and overall acceptability of the participants
12. Food or fad? Challenges and opportunities for including seaweeds in a Nordic diet (Chapman, Stévant & larssen, 2015)	Four studies: Study 1: Four species of seaweed either dried, or rinsed in cold water and microwaved Study 2: Three species of seaweed Study 3: 17 different dishes with seaweed ingredients Study 4: Fish cakes with and without saccharina latissima (brown algae sugar kelp)	Four studies: Study 1: Keywords associated with texture, flavour and mouth-feel attributes of different seaweed species Study 2: Eleven taste, flavour and mouth-feel qualities in a quality control test Study 3: The taste of the dishes and the opinion of the chefs regarding the use of seaweed when preparing the dishes Study 4: The taste of the study participants
13. The influence of product attributes, consumer attitudes and characteristics on the acceptance of: (1) Novel bread and milk, dietary supplements and (2) fish and novel meats as dietary vehicles of long chain omega 3 fatty acids (Cox, Evans & Lease, 2011)	Bread, milk and supplements	Preferred source of oil (fish oil, algal oil and novel oilseed) of the participants

Paper		
14. Chemical and sensory analysis of strawberry flavoured yogurt supplemented with an algae oil emulsion (Chee et al., 2005)	Three different samples of strawberry flavoured yogurt	The perceived fishy flavour and liking of taste of the participants

*Some papers measure more than just perception of algae and seaweed, but in this report, the independent and dependent variables are listed in the way that they are relevant for this literature review.

Table 3: Scope of research of the empirical papers

Paper	Data gathering method used	Description of targeted subjects	Number of participants/ respondents
1. The potential of edible seaweed within the western diet. A segmentation of Italian consumers (Palmieri & Forleo, 2020)	Web-based survey	Italian consumers aged 18 to 69 years (mean of 36 years). 58% female, 42% men	257
2. Preference and willingness to pay for meat substitutes based on micro-algae (Weinrich & Elshiewy, 2019)	Survey	Consumers from Germany, France and The Netherlands with a mean age of respectively 34, 32 and 32. Female ratio 0.51 of all countries.	Germany: 315 France: 315 The Netherlands: 308 <u>Total:</u> 938
3. Seaweed consumption and label preferences in France (Lucas, Gouin & Lesueur, 2019)	Online pre-survey and a questionnaire completed via in-person interviews in seven major French cities	French consumers aged 15 - 60+. Female ratio of 0.52	Pre-survey: 123 In-person questionnaire: 495
4. Who Eats Seaweed? An Australian Perspective (Birch, Skallerud & Paul, 2019)	National online survey	Australian consumers aged 18 – 60+. 38.8% male, 60.5% female	502

5.	Inuit Perception of Marine Organisms: From Folk Classification to Food Harvest (Rapinski, Cuerrier, Harris & Lemire, 2018)	Twelve qualitative interviews	Elders from an Inuit community in Kangiqsujuag (mean age 73) & Ivujivik (mean age 67), (Nunavik, Canada).	15
6.	Consumer-Oriented Product Development: The Conceptualization of Novel Food Products Based on Spirulina (Arthrospira platensis) and Resulting Consumer Expectations (Grahl, Strack, Weinrich & Mörlein, 2018)	Online survey distributed through a commercial, established company	Consumers from Germany, France and The Netherlands aged 18 – 64. Female ratio respectively 53%, 52% and 53%.	Germany: 348 France: 337 The Netherlands: 350 Total: 1035
7.	Public perception of algal consumption as alternative food in the Kingdom of Bahrain (Al-Thawadi, 2018)	Two experiments and a questionnaire	In general: consumers from the Kingdom of Bahrain Experiment 1: people from the University of Bahrain aged 16-60. Majority were male. Experiment 2: people from different sectors and social ranks. Data about age and gender unknown. Questionnaire: consumers from different segments of the Bahraini community. Most of them were 16 – 20 years old. 81% was male.	Experiment 1: 30 Experiment 2: 1000 Questionnaire: 300

8. Key-Narratives of Microalgae Nutrition (Rossmann & Rösch, 2018)	Delphi-survey	German consumers with an average age of 36. Female ratio higher than male ratio.	229
9. Microalgal food supplements from the perspective of Polish consumers: patterns of use, adverse events, and beneficial effects (Rzymski & Jaśkiewicz, 2017)	Nationwide online survey	Polish consumers with a mean age of 35 years old. 76% female, 24% men.	150
10. Development of formulations for reduced-sugar and sugar-free agar-based fruit jellies (Riedel, Böhme & Rohm, 2015)	Sensory evaluation of three tests. Test 1: untrained panel with no information about the samples Test 2: untrained panel with only the knowledge of one sugar-free sample Test 3: Just-about-right (JAR) acceptance test	Test 1: Student evaluators Test 2: Student evaluators Test 3: Consumers with a mean age of 33.5. 58% female, 42% men.	Test 1: 72 Test 2: 82 Test 3: 60
11. Evaluation of the Cooking Quality Characteristics of Pasta Enriched with Spirulina Platensis (Özyurt et al., 2015)	Sensory panel	Turkish panellists who were trained academic staff	7
12. Food or fad? Challenges and opportunities for including seaweeds in a Nordic diet (Chapman, Stévant & larssen, 2015)	Four studies: Study 1: Untrained sensory panel Study 2: Trained panel Study 3: Trained panel and volunteers for tasting panel	Four studies: Study 1: Norwegian judges aged 28 to 58, all had limited experience with sensory profiling of seaweed Study 2: Norwegian chefs aged 17 to 65 that worked	Four studies: Study 1: 15 Study 2: 7 Study 3: 7 seven chefs and 17 volunteers Study 4: 103

	Study 4: Consumer test that existed of a tasting panel and a survey (untrained)	regionally (Alesund) with Nordic food traditions. Four of these chefs had experience with cooking seaweed Study 3: The same chefs as study 2 and some volunteers (no further information available) Study 4: Norwegian consumers. 58% male, 42% female.	
13. The influence of product attributes, consumer attitudes and characteristics on the acceptance of: (1) Novel bread and milk, dietary supplements and (2) fish and novel meats as dietary vehicles of long chain omega 3 fatty acids (Cox, Evans & Lease, 2011)	Questionnaire	American consumers from Redwood City CA and Buffalo Grove IL (USA). Age range of 35-75. Male/female ratio 50/50.	202
14. Chemical and sensory analysis of strawberry flavoured yogurt supplemented with an algae oil emulsion (Chee et al., 2005)	Trained panel and consumer panel	Trained panel: no demographic information available. The members were trained to recognize fishy off-flavours in ten sessions. Consumer panel: Members of the State University of Pennsylvania who occasionally consumed strawberry yogurt	Trained panel: 10 Consumer panel: 239