Attitudes and perceptions towards microalgae as an alternative food: A consumer segmentation in Switzerland

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ABSTRACT

Microalgae can be considered an alternative food with a great future in the food industry due to their nutritional composition and sustainable benefits. In this context, this study aimed to identify segments of consumers in Switzerland regarding their attitudes and perceptions towards microalgae-based foods, describing their behavioural patterns and sociodemographic characteristics. Flyers containing a link to an online survey were sent to randomly selected postal codes in Switzerland. After data cleaning, 584 questionnaires remained. Cluster analyses were performed to segment consumers, and six distinguished consumer segments were identified. The results indicated four segments with a more positive attitude towards microalgae: 'microalgae supporters and health eaters,' 'innovative and adventurous', 'aware and open-minded' and 'uninformed but susceptible.' These segments were, therefore, more open to accepting and consuming microalgae-based foods. Strategies for reaching these segments, as well as the ones more sceptical towards microalgae, named 'conservatives' and 'microalgae avoiders and traditional', were proposed. This information can be valuable for microalgae producers, marketers and policymakers, helping to increase the demand for these alternative and sustainable foods.

1. Introduction

Nowadays, there is increasing concern about how to offer the population worldwide access to healthy and sustainable diets aimed at overcoming hunger and food insecurity [1]. Among the promising sources of alternative proteins that can promote a more sustainable diet are pulses, seaweed and microalgae [2–4]. Microalgae can be naturally found in freshwater and marine aquatic systems and are a source of nutrients such as carotenoids and omega-3. Furthermore, microalgal biomass can be produced in non-arable lands, such as urban areas [5–7]. These organisms are capable of mitigating CO_2 and potential to be applied in several practices such as the development of food packaging, wastewater treatment, and reducing environmental pollution [5,8,9].

Some microalgae are considered health foods, functional foods, or 'superfoods' [6,7]. Microalgae such as *Spirulina* and *Chlorella* contain high amounts of nutrients and antioxidants and can be used to develop alternatives to meat, being considered sustainable alternative ingredients. Proteins from microalgae can contribute to the global population's need for protein [5,10–12]. Despite this, the number of microalgae-based foods available in the market is considered limited [5,13,14].

Food choice involves the sensory characteristics of the food, as well as the consumer's expectations and attitudes, which can highly differ from each other [15]. In this context, segmentation has been applied in strategic marketing and consumers with similar characteristics have been grouped [16]. Segmentation allows companies to focus on specific target groups and develop different interventions that are effective for each specific segment [17,18]. Lucas et al. [19] investigated the perceptions of Swiss consumers towards 'superfoods' and obtained six segments where the segments that consume more 'superfoods', named 'superfoodies' and 'involved', showed higher nutritional knowledge, interest in organic food and safety of food. Moons et al. [20] investigated the intention of Belgian consumers to adopt microalga-enhanced foods. Among the identified consumers, 'foodies', 'sporting individuals' and 'vegetarians' showed higher interest in microalga-enhanced food.

Studies have investigated consumers' perceptions and attitudes towards alternative proteins [2,21]. Despite this, studies on consumer perception towards microalgae [3,6,20,22,23] can be considered limited compared to other protein sources, such as insects and pulses [4].

Switzerland is characterized as an innovation leader [24], including in the field of alternative foods [25], and for this reason, chosen to

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conduct this survey. To the best of our knowledge, no segmentation study in the context of microalgae-based foods has been conducted in Switzerland. Moreover, compared to earlier studies, we used validated scales to segment the consumers that have not been used before. Thus, this study aimed to identify segments of Swiss consumers regarding their attitudes and behaviours and to propose target groups for microalgae consumption. These results can support the food industry, food retailers, the marketing sector, and policymakers helping to increase microalgae-based food demand and consumption.

2. Materials and methods

2.1. Online questionnaire

A questionnaire containing several items was developed in English and then translated into German and French (to reach different parts of Switzerland). Afterwards, the questionnaire was transferred to an online tool (Unipark online survey software).

Flyers explaining the aim of the study and containing a link to the questionnaire were sent to a random sample of postal codes from January to February 2023. Before starting the survey, the participants agreed to provide informed consent and were informed that they were able to drop out of the survey at any time. The study was performed following the Guidelines for Ethical Conduct in Research from Bern University of Applied Sciences (reference n° EAB2022-020).

2.2. Participants and characteristics

A total of 618 participants completed the survey, and 34 cases were excluded because they failed the instructional manipulation check. A sample of $n = 584$ was considered for further analysis. Among them, 21.2 % declared age between 18 and 39 years old, 40.3 % between 40 and 59 years old and 38.5 % with 60 years old or more.

The final sample comprised 55.6 % females and 44.4 % males, 89.6 % of whom were responsible for buying food and 84.6 % were responsible for cooking in their households. Furthermore, 57 % declared being omnivores (diet with meat, fish and/or seafood), 33.6 % flexitarians (diet mainly vegetarian with occasional meat or fish consumption), 6.7 % vegetarians (no meat, fish or seafood consumption) and 2.7 % vegans (without animal products).

Among the participants, 95 % had Swiss nationality, while 5 % were from other countries and 32.9 % worked full-time, 35.9 % worked part-time, and 31.2 % were not working. Moreover, 79.4 % of the participants declared having finished the tertiary degree (higher vocational education/applied school/university), while 17.9 % reported having finished secondary level and only 2.7 % completed the mandatory school or declared 'none' as their level of education.

2.3. Measures

2.3.1. Information about microalgae and diet type selection

At the beginning of the survey, participants were asked to choose their diet type among omnivores, flexitarians, vegetarians or vegans. Then, the definition of microalgae and arguments in favour of these foods were presented as follows:

- Definition: '*Microalgae can be naturally found in the environment, in freshwater and marine aquatic systems, and are a source of nutrients such as carotenoids and omega-3. Some microalgae are considered health foods, functional foods, or 'superfoods'. Microalgae such as Spirulina and Chlorella contain a high amount of nutrients and antioxidants. Proteins from microalgae can contribute to the global population's need for protein, being considered promising candidates for meat substitutes*'.
- Health argument: '*Some microalgae contain high-quality proteins and all the essential amino acids that the human body needs to stay healthy. The high concentration of nutrients, especially the bioactive compounds of*

microalgae, can contribute to improving health. For example, the compounds in microalgae biomass can have an antioxidant effect, which can prevent diseases*'.
- Food security argument: '*Hunger affects millions of people globally and the COVID-19 pandemic added to the total number of those who are already undernourished. Furthermore, the population is expected to achieve 9.8 billion in 2050. To ensure food security for the world's population, there is currently a great deal of research into alternative sources of protein. Microalgae are one of the most promising options*'.
- Sustainability argument: '*Microalgae do not require arable land and hence do not compete with other food crops. Furthermore, microalgae cultivation demands less water than that required by other protein-rich foods. Microalgae production can also help to reduce atmospheric pollution by capturing CO_2. Finally, the high-quality protein of microalgae could partially replace animal protein, which would once again lead to a better ecological balance of the human diet*'.
- Animal welfare argument: '*Animals are capable of experiencing stress and pain. Consuming microalgae as an alternative protein could reduce meat consumption, contributing to animal welfare*'.

The arguments were selected based on the previous literature on consumer behaviour [3] with modifications.

2.3.2. Clustering variables

Consumers were segmented based on psychometric and behavioural variables related to microalgae, accounting for 15 items in total (Table 1). These scales were also presented in the first part of the questionnaire using 6-point Likert scales ranging from 1-strongly disagree to 6-strongly agree. However, the 'attitude towards microalgae in food' was presented initially as a semantic differential scale and was queried varying from −3 to +3, excluding 0, and later recoded to

Table 1
Clustering variables (6-point Likert scale).

Scale	Reference
Attitude towards microalgae in food (Cronbach's α 0.95)	Based on Lucas et al. [26]
I think that the use of microalgae in food…	
Not interesting – Interesting	
Not worth trying – Worth trying	
Not to be supported – to be supported	
Negative – Positive	
Previous knowledge on microalgae[a] (Cronbach's α 0.85)	Based on Lucas et al. [19]
How much do the following statements apply to you?	
I've already read/heard a lot about microalgae	
I already knew about these facts	
I noticed that microalgae were presented in the media	
Health benefit perception[b] (Cronbach's α 0.87)	Based on Lucas et al. [27]
How much do the following statements apply to you?	
Microalgae offer a significant advantage in terms of health	
These arguments could make me consume microalgae	
This information makes me curious to try microalgae	
These arguments could make me reduce meat consumption[c]	
Position on microalgae (Cronbach's α 0.86)	Based on Lucas et al. [19]
How much do the following statements apply to you?	
Microalgae/microalgae-based foods are foods with a great future in the food industry	
I can imagine buying and consuming microalgae/microalgae-based foods regularly	
I would be willing to pay a little more for microalgae/microalgae-based foods than for vegetables	
I would be willing to pay a little more for microalgae-based meat substitutes than for meat	

[a] Participants' answers were based on the given definition of microalgae (see Subsection 2.3.1).

[b] Participants' answers were based on the given health argument (see Subsection 2.3.1).

[c] This statement was filtered out in the questionnaires from vegans and vegetarians.

Table 2

Scales and items used to describe the segments and Cronbach's α.

Parameters/scales	Cronbach's α
1. Sustainability (related to meat production and consumption) [29]	0.85
If people in the world ate less meat, there would be enough food for everybody	
To slow down climate change, meat consumption should be considerably reduced	
Meat production is unethical	
2. Cooking creativity [30]	0.86
Cooking allows me to express my creativity	
When I cook, I like to try new recipes	
The best of cooking is to develop own recipes or optimize existing ones	
3. Self-reported health status [31]	0.84
I feel physically healthy	
I am very physically active	
I regularly play sports	
4. Food neophobia [32]	0.58
I don't trust new foods	
If I don't know what is in a food, I won't try it	
I am afraid to eat things I have never had before	
I am very particular about the foods I will eat	
5. Food technology neophobia [33]	0.83
There are plenty of tasty foods around so we don't need to use new food technologies to produce more	
The benefits of new food technologies are often grossly overstated	
New food technologies decreases the natural quality of food	
There is no sense trying out high-tech food products because the ones I eat are already good enough.	
6. General health interest [34]	0.78
The healthiness of food has little impact on my food choices[R]	
I am very particular about the healthiness of food I eat	
I eat what I like and I do not worry much about the healthiness of food[R]	
7. Price/quality relation [35]	0.66
I always try to get the best quality for the best price	
I compare the prices between product variants in order to get the best value for money	
It is important for me to know that I get quality for all my money	
8. Food involvement [36]	0.64
I don't think much about food each day[R]	
Talking about what I ate or am going to eat is something I like to do	
I enjoy cooking for others and myself	
I care whether or not a table is nicely set	
9. Environmental protection[a] [37]	0.88
Has been prepared in an environmentally friendly way	
Is packaged in an environmentally friendly way	
Has been produced in a way which has not shaken the balance of nature	
10. Sensory appeal[a] [38]	0.76
Smells nice	
Looks nice	
Has a pleasant texture	
Tastes good	
11. Natural content[a] [38]	0.88
Contains no additives	
Contains natural ingredients	
Contains no artificial ingredients	
12. Familiarity[a] [38]	0.74
Is what I usually eat	
Is familiar	
Is like the food I ate when I was a child	
13. Mood[a] [38]	0.62
Keeps me awake/alert	
Cheers me up	
Makes me feel good	
14. Nutritional knowledge[b] (based on [39])	0.51
Lentils contain only few useful nutrients; therefore, their health benefit is not great[R]	
All dietary oils have the same ingredients; the oils differ only in taste[R]	
Fat is always bad for your health; you should therefore avoid it as much as possible[R]	
Whole meal foods contain fiber, which is of no use for digestion[R]	
If chips did not contain so much salt, you could eat more of them without any problem[R]	
A healthy diet means nothing more than eating vitamins[R]	

Legend: [R]: Negative items were reversed.

Scales from 1 to 13 ranging from 1 = Strongly disagree to 6 = Strongly Agree; Scale 14: Options 'incorrect', 'correct', 'don't know', with scores from 0 (no correct answers) to 12 (all answers correct).

[a] Introductory statement: 'It is important to me that the food I eat on a typical day:'

[b] Introductory statement: 'Please indicate, in your opinion, if these statements are true or false.'

the range 1 to 6 at the data treatment step.

2.3.3. Variables used to describe the segments

Behavioural and sociodemographic variables were used to describe the clusters. Aiming to limit the length of the survey, the number of items was reduced in some of the validated scales [27]. These variables were selected based on the assumption that they are related to the perceptions towards microalgae [19,20]. The scales related to behavioural patterns were queried on a 6-point Likert scale (1-strongly disagree, 2-disagree, 3-somewhat disagree, 4-somewhat agree, 5-agree and 6-strongly agree), where [R] means that the item was reversed for analyses (Table 2). Six-point Likert scales were applied to avoid no-opinion options [28].

To evaluate the *frequency of consumption of microalgae/microalgae-based foods* and *meat substitutes (made from vegetable proteins, such as peas and soybeans)*, participants had to state the following: 1) never, 2) <1× per month, 3) 1–3× per month, 4) 1–2× per week, 5) 3–4× per week, 6) 5–6× per week or 7) every day. In the end, sociodemographic information, including sex, age, nationality, education and employment status, was queried.

2.4. Segmentation and statistics

Segmentation was conducted using variables related to microalgae. These variables (Table 1) were selected based on a theoretical basis since they offer a unique differentiation of the objects. Correlation tests indicated that they were not highly correlated (<0.8), resulting in no cause for concern [18]. To assess the consistency of the scales, Cronbach's α was applied. All scales applied for the segmentation (Table 1) showed a Cronbach's α higher than 0.8, which is highly suitable. Some of the scales used to describe the segments displayed a lower Cronbach's α, however, since these were all validated scales, we decided to keep them.

For segmentation, the data were first verified regarding the presence of outliers, where one case was removed, resulting in a sample of 583 participants. Then, the following approach combining two clustering methods was used: I) Hierarchical clustering using Ward's linkage method based on squared Euclidean distance, was applied to identify the number of clusters and the clusters' centroids. To define the number of clusters, changes in the agglomeration coefficient (or agglomeration schedule) and dendrogram were observed. Based on this observation, four and six-cluster solutions emerged as possible solutions. Next, the variance ratio criterion (VRC) was calculated and the cluster

Table 3
Mean ± standard deviation obtained for the four clustering variables and results from contrast test by segment.

Measures	Segments						Overall mean
	Microalgae supporters and health eaters	Innovative and adventurous	Aware and open-minded	Uninformed but susceptible	Conservatives	Microalgae avoiders and traditional	
Attitude towards microalgae in food	5.80 ± 0.37	5.57 ± 0.54	5.31 ± 0.58	4.36 ± 0.78[ns]	3.84 ± 0.86	1.87 ± 0.91	4.77 ± 1.28
Previous knowledge on microalgae	4.69 ± 0.69	2.24 ± 0.76	3.57 ± 0.57	1.75 ± 0.59	3.76 ± 0.75	1.80 ± 1.02	3.03 ± 1.31
Health benefit perception	5.20 ± 0.54	4.96 ± 0.52	4.22 ± 0.50	3.83 ± 0.63[ns]	3.19 ± 0.72	2.04 ± 0.76	4.13 ± 1.08
Position on microalgae	4.85 ± 0.68	4.63 ± 0.59	3.68 ± 0.52	3.39 ± 0.59[ns]	2.52 ± 0.68	1.80 ± 0.66	3.69 ± 1.11

Legend: $p < 0.001$ for all results except for the indicated with superscript [ns], where $p > 0.05$.
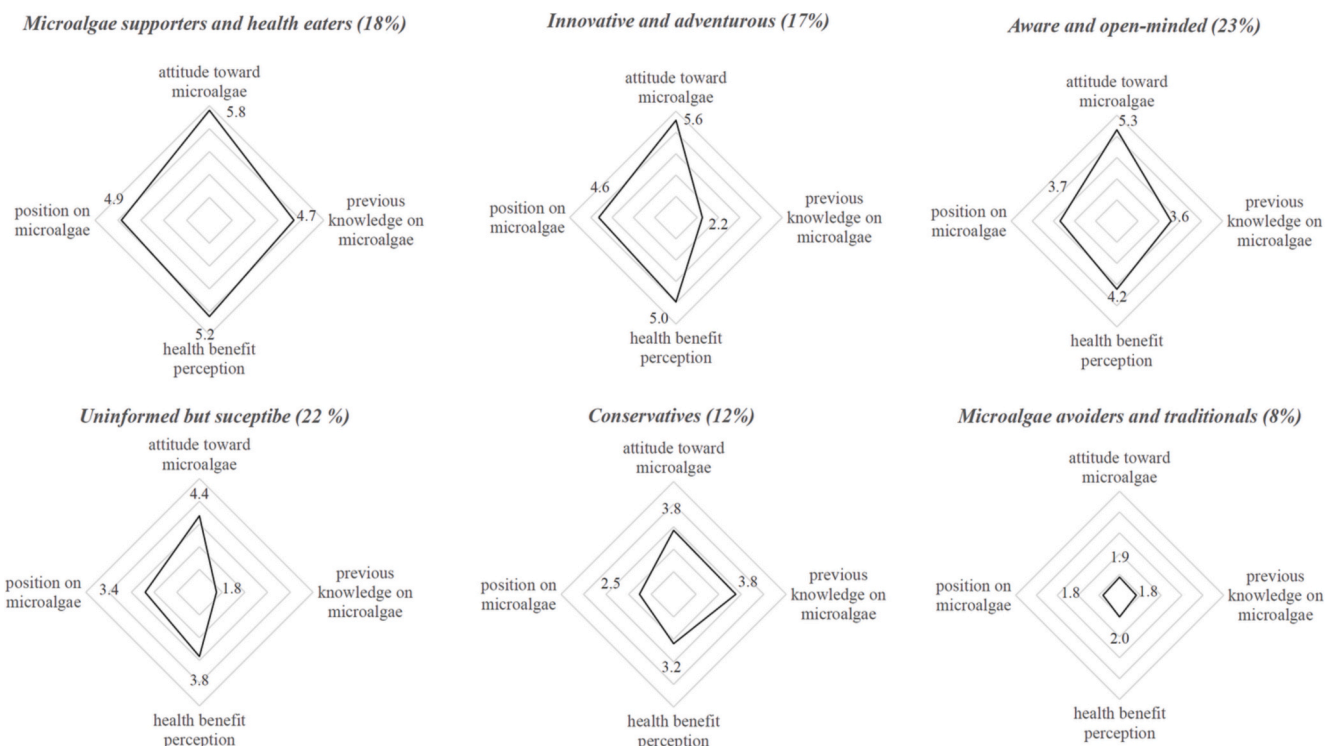

Fig. 1. Segments of consumers in the selected six-cluster solution ($n = 583$).

distributions were observed. In the end, six-cluster solutions (CS6) were chosen as the best solution and the centres of the clusters obtained for this solution were used as input and starting points for the K-means analyses [18,40]. II) The partitioning method K-means was conducted and the stability of cluster solution six was verified by exploring the overlap of the results obtained by the hierarchical clustering using Ward's linkage method and K-means clustering [18]. The overlap obtained was 80 %. Finally, the clusters/segments forming the selected cluster solution (CS6) obtained by K-means were described using scales related to behavioural patterns and sociodemographic characteristics in the profiling step. The significance of the variables was determined through one-way ANOVA, contrast tests and Chi-square (for the dichotomous variables). All statistical analyses were conducted using IBM SPSS Statistics (v.28).

3. Results

The six-cluster solution was formed by six groups with different perceptions towards microalgae-based foods (Table 3, Fig. 1): 'microalgae supporters and health eaters', 'innovative and adventurous', 'aware and open-minded', 'uninformed but susceptible', 'conservatives' and 'microalgae avoiders and traditional'.

3.1. Microalgae supporters and health eaters (n = 106; 18 %)

This cluster comprised 18 % of the evaluated sample. Microalgae supporters and health eaters claim to have previous knowledge of microalgae. Moreover, consumers in this segment have a highly positive attitude towards microalgae-based foods, believe in the health benefits of microalgae and have a positive position towards these foods, as observed in the significantly higher scores ($p < 0.001$) of all clustering variables compared to other clusters (Fig. 1, Table 3). This share of consumers has a higher willingness to pay a little more for microalgae-based foods than for conventional protein sources and believes in microalgae having a great future in the food industry (Table 3).

This cluster already consumes microalgae more frequently than

other segments ($p < 0.001$) and has the second-highest consumption rate of meat substitutes ($p < 0.001$). This does not come as a surprise in a cluster composed of the lowest share of omnivores ($p < 0.001$) (Table 4).

Furthermore, consumers in this segment agree, more than the other segments, that sustainability can be related to a reduction in meat production and consumption ($p < 0.001$). They are characterized by low food neophobia ($p < 0.05$) and low food technology neophobia ($p < 0.001$), with the second-lowest score among all clusters. This finding is in line with low interest in familiar foods ($p < 0.001$), the second-lowest score among the clusters (Table 4).

Microalgae supporters and health eaters show the highest food involvement ($p < 0.001$) and interest in environmental protection ($p < 0.001$) across the segments. They worry most about the healthiness of the food they eat ($p < 0.001$) and have the highest interest in the natural content of food ($p < 0.001$) and sports and physical activities ($p < 0.01$) compared to other clusters (Table 4).

Furthermore, consumers in this cluster are more oriented by the relation between price and quality of food ($p < 0.05$) and more interested in food that is pleasant to their senses ($p < 0.01$) and that makes them feel in a good 'mood' ($p < 0.001$) compared to other clusters (Table 4).

These consumers are the most interested in cooking using creative recipes ($p < 0.001$), besides having the second-highest nutritional knowledge ($p < 0.01$). The microalgae supporters and health eaters' segment is composed of a significantly ($p < 0.001$) higher share of females (Table 4).

3.2. Innovative and adventurous (n = 97; 17 %)

Innovative and adventurous consumers have a positive attitude towards microalgae (second-highest among all segments), even though they lack previous knowledge on microalgae (third-lowest across the segments) ($p < 0.001$) (Fig. 1, Table 3). They believe that microalgae are interesting and worth trying, besides offering advantages in terms of health. They intend to eat more microalgae in the future and are willing to pay a little more for microalgae than for conventional food such as

Table 4
Results obtained on describing variables and results from contrast test by segment.

Measures	Segments						Mean
	Microalgae supporters and health eaters	Innovative and adventurous	Aware and open-minded	Uninformed but susceptible	Conservatives	Microalgae avoiders and traditional	
Sustainability	**4.92****	**4.88****	4.08**	3.71	2.93***	*2.34****	4.01
Cooking creativity	**4.92****	4.39	4.38	4.19*	4.55	*4.01***	4.43
Self-reported health status	**4.90****	4.55	4.67	4.57	4.59	4.59	4.65
Food neophobia	2.98*	*2.78****	3.05	2.98*	3.35*	**3.81****	3.08
Food technology neophobia	3.06***	*2.82****	3.36***	3.53	4.34***	**4.70****	3.48
General health interest	**5.14****	4.89***	4.52	4.30**	4.60	*3.81****	4.60
Price-quality relation	**4.42***	4.14	4.19	4.15	4.31	4.13	4.22
Food involvement	**4.55****	4.14	4.31	4.17	4.35	*4.05**	4.28
Environmental protection	**5.39****	5.06***	4.80	4.59**	4.84	*3.92****	4.83
Sensory appeal	**5.10****	*4.81**	4.88	4.92	5.07	4.86	4.94
Natural content	**5.31****	4.84	4.73	4.58**	5.09**	*4.30****	4.83
Familiarity	3.15***	*3.13****	3.52	3.57	3.70	**4.05****	3.47
Mood	**4.42****	4.07	4.07	4.05	4.16	3.88	4.12
Nutritional Knowledge	11.42**	**11.46****	11.06	11.23	11.25	*10.10***	11.17
Diet type[a] (% of omnivores)	*37****	43***	56	66	71*	**92****	57
Sex[b] (% of males)	*30****	47	42	44	49	**71****	44
Age (in years)	55.45	*50.63**	53.13	50.70*	55.82	57.51	53.28
Microalgae consumption (days/week)	**0.90****	0.15	0.24	0.03***	0.05***	*0.01****	0.26
Meat substitute consumption (days/week)	1.48***	**1.56****	0.71	0.52**	0.52*	*0.13****	0.88

Legend: *In the same line indicates significant differences among the segments, where ***$p < 0.001$, **p < 0.01 and *p < 0.05; values in **bold**: highest score; values in *italic*: lowest score.
Scales evaluated on a 6-point Likert scale, except 'Nutritional knowledge'; maximum 12 points for all correct answers.
[a] Diet type: 1 = omnivore, 0 = other (flexitarian, vegan or vegetarian).
[b] Sex: 1 = male, 0 = female.

vegetables and meat (p < 0.001).

The healthiness of food has a great impact on their food choices, as illustrated by them having the second-highest score in general health interest (p < 0.001). Compared to other clusters, they show significantly higher general nutritional knowledge (*p* < 0.01). For these consumers, the sensory appeal of food is still important; however, they place the least importance on this of all segments (*p* < 0.05) (Table 4).

The innovative and adventurous are interested in food produced, packaged and prepared in an environmentally friendly way (*p* < 0.001). Participants of this cluster are the youngest (*p* < 0.05) and mostly non-omnivores (p < 0.001), including flexitarians, vegetarians and vegans. They believe excess meat production and consumption to have a negative effect on sustainability, with the second-highest score on the scale 'sustainability' (*p* < 0.001). These consumers are open-minded and have the lowest phobia towards novel foods and novel technology used to produce food across the segments (p < 0.001); therefore, their lowest interest in familiar and traditional foods (*p* < 0.001) does not come as a surprise. Consumers in this group already consume meat substitutes (based on vegetable proteins such as peas and soybeans) more frequently than other segments (*p* < 0.001) (Table 4).

3.3. Aware and open-minded (n = 135; 23 %)

Aware and open-minded consumers, the largest cluster, have a positive attitude towards microalgae (third-highest score) and, after receiving information about them, agree on the health benefits of these foods (*p* < 0.001) (Fig. 1, Table 3). They also have a low phobia towards novel food technology (*p* < 0.001), and for this reason, they are named 'open-minded' (Table 4). They showed a neutral position towards microalgae and claimed to have some previous knowledge about the topic (Table 3).

This group of consumers is composed of 44 % of non-omnivores and probably because of that show the third higher score (*p* < 0.01) on the scale sustainability (Table 4), meaning that they are aware of the negative effects of excessive meat production and consumption on sustainability.

3.4. Uninformed but susceptible (n = 128; 22 %)

The second largest segment is composed of consumers with the second-lowest mean age (*p* < 0.05) (Table 4). Consumers in this group are not informed about microalgae, as observed by the lowest score for previous knowledge on microalgae (*p* < 0.001) among all segments (Fig. 1, Table 3). They consume microalgae rarely, being the group with the second-lowest (*p* < 0.001) consumption frequency (Table 4). Despite this, the average attitude towards microalgae for this segment is still positive (>4, on a 6-point Likert scale) (Table 3).

Although they show a low phobia towards new foods (p < 0.05), their consumption of meat substitutes is the second lowest among the clusters (*p* < 0.01) (Table 4). Considering that the results were based on a 6-point Likert scale, uninformed but susceptible consumers showed some interest in general health and environmental protection, however, not as much as other segments (Table 4).

3.5. Conservatives (n = 68; 12 %)

Conservatives represent the second smallest segment, accounting for 12 % of the total sample. They scored neutral to slightly positive on the scales for attitude towards microalgae and previous knowledge of microalgae, and slightly negative on health benefit perception (p < 0.001) (Fig. 1, Table 3). Furthermore, they do not believe microalgae have a great future in the food industry and they are not willing to pay more for microalgae than for conventional protein sources, as observed in the negative score on the scale position on microalgae (Table 3).

Consumers in this group showed a high phobia towards new technologies used to produce food, with the second-highest scores for food

technology neophobia (*p* < 0.001). For this reason, they were named 'conservatives' (Table 4). This segment consumes microalgae or microalgae-based foods almost never (*p* < 0.001). Furthermore, their consumption of meat substitutes is low, the third lowest among the segments (*p* < 0.05) (Table 4).

They are composed mostly of omnivores (p < 0.05), being the group with the second largest omnivore composition. That is probably the reason they show the second lower score (p < 0.001) on the sustainability scale, meaning that they do not agree that excess meat production and consumption negatively affect climate change and food security, respectively. Despite this, they look for food made with natural ingredients that contain no additives or artificial ingredients, with the second-highest score in natural content (*p* < 0.01) (Table 4).

3.6. Microalgae avoiders and traditional (n = 49; 8 %)

Microalgae avoiders and traditional consumers constitute the smaller group, representing 8 % of the sample evaluated. Consumers in this group are more sceptical of the use of microalgae as food than other segments. They scored significantly lowest in all clustering variables related to microalgae (*p* < 0.001), except in previous knowledge of microalgae (*p* < 0.001) (second-lowest score) (Fig. 1, Table 3).

They do not believe in a future of microalgae in the food industry and they do not have the intention to buy or consume these foods regularly. Moreover, they do not agree that microalgae offer benefits in terms of health improvement (*p* < 0.001) (Table 3), even after receiving some information on the subject. These results are in line with consuming little to no microalgae or microalgae-based foods (*p* < 0.001) by these consumers (Table 4).

Their general nutritional knowledge is the lowest (p < 0.01) across the segments. Moreover, they are more interested in familiar foods (p < 0.001) and show significantly higher food neophobia (p < 0.001) and food technology neophobia (p < 0.001) compared to other segments (Table 4).

Consumers in this group are less involved with food (p < 0.05) and less interested in being creative while cooking (p < 0.01), and in environmental protection (p < 0.001) compared to other segments. Their general health interest and their interest in food with natural content are also the lowest (p < 0.001) compared to other segments.

Microalgae avoiders and traditional consumers are mostly omnivores and males (p < 0.001). These consumers do not believe that excess meat production is unethical and negatively impacts sustainability (p < 0.001); thus, the significantly lower consumption rate of meat substitutes (p < 0.001) made from vegetable proteins does not come as a surprise.

4. Discussion

The results showed that behavioural patterns have a higher influence on segment differentiation compared to sociodemographic variables. Previous research has also reported that demographic variables are less relevant than social and psychological factors when evaluating the acceptance of alternative proteins [4].

In the present study, four of the six segments obtained—'microalgae supporters and health eaters', 'innovative and adventurous', 'aware and open-minded' and 'uninformed but susceptible'—showed a positive attitude towards microalgae and a certain openness and should be considered the primary target groups for microalgae-based foods. In line with our study, Moons et al. [20] also reported that consumers who are more health conscious are more willing to adopt microalga-based foods.

The segment 'microalgae supporters and health eaters' showed the highest scores for all the microalgae-based scales, having, for example, a higher previous knowledge, perception of microalgae being healthy and higher willingness to pay more for microalgae-based foods than the other five clusters. However, their consumption rate of microalgae-based foods is less than one day per week. This finding is interesting

for the marketing sector to consider and can be related to the current low variety of microalgae-based foods available in the market compared to other alternative foods, such as those made from peas and soybeans. As this cluster has a low phobia towards novel food technology and a high interest in the natural content of food, offering processed microalgal-based foods such as ready-to-eat snacks [41] or meat analogues [11] containing no additives or artificial ingredients may be interesting. Furthermore, these consumers were the most interested in the relationship between the price and quality of foods; therefore, offering microalgae-based foods at competitive prices can be considered another important approach to reach them. As these consumers are involved with food and interested in the natural content and sensory aspects of the food they eat, another suggestion could be that restaurants increase their offers of microalgae-based meals using natural ingredients and creative recipes. In the gastronomy sector, initiatives to promote the consumption of edible seaweeds through creative recipes already exist [42].

Among the segments 'innovative and adventurous', 'aware and open-minded' and 'uninformed but susceptible', an interesting approach to increasing the consumption of microalgae-based foods could be providing information about the benefits of this alternative food. These consumers lacked previous knowledge of microalgae; however, after initiating the survey and receiving some information, they were able to perceive microalgal health benefits, for example. According to Onwezen et al. [4], consumers frequently do not have information on the health and environmental benefits of consuming alternative proteins; however, after being informed, this behaviour seems to have changed positively. Lucas et al. [19] suggested ways to increase consumer knowledge of superfoods, such as microalgae, through events and exhibitions where consumers could gain knowledge on the topic and learn new recipes, for example. Giving consumers the opportunity to taste unknown food can be considered another tool to increase consumers' interest [42].

For 'conservative' consumers who have an interest in foods containing natural ingredients but have some concerns about microalgae, detailed information about microalgae's naturalness can be provided. According to Henn et al. [2], reservations can come from some consumers perceiving certain foods as unnatural or processed. Thus, one possibility to reach 'conservative' consumers after providing them with information can be offering dishes containing no additives or artificial ingredients that are made from well-known natural ingredients and microalgae.

Regarding the high food neophobia in the segment 'microalgae avoiders and traditional', the findings are comparable with other studies that evaluated the aversion of consumers to trying novel alternative protein foods such as seaweed and insects [4]. For these neophobic and sceptical consumers with a high interest in familiar and traditional foods, where the potential to increase microalgae consumption is lower than in other segments, offering microalgae-based meals that resemble traditional dishes and what they usually eat may be an option [19]. Developing processed, well-known products, such as wraps, using alternative proteins as ingredients can be another way to increase the acceptance of these foods among consumers interested in familiar foods [4]. Additionally, the use of microalgae, such as Golden *Chlorella*, in recipe preparation can facilitate consumer acceptance, as the intense colour of some microalgae can be considered a barrier to potential consumers.

According to Weinrich and Gassler [43], the ecological impact of meat consumption is often underestimated by consumers. Thus, for the segments more sceptical towards microalgae, with the greatest share of omnivores that do not agree that excess meat production and consumption negatively affect climate change, food security and sustainability in general, the focus should be on providing information. Inform consumers may result in increased sustainable food choices [44].

Regarding the sociodemographic influence, the results showed that the segment most open to microalgae-based foods, 'microalgae supporters and health eaters', was composed of a significantly high share of non-omnivores (63 %) and females (70 %), which can also be interesting to marketing sectors to consider and set strategies. This finding is in line with the results obtained by previous research on consumer attitudes towards alternative proteins [2,17,21]. However, Weinrich and Gassler [43] study found men more likely to buy microalgae-enhanced food and suggested that these individuals should also be considered target groups.

Despite the interesting findings, a limitation should be pointed out. The sample evaluated was composed mostly of respondents with Swiss nationality (95 %). However, according to the Federal Statistical Office [45], among the permanent resident population in Switzerland, about a quarter is composed of foreign nationals. Thus, to be more representative of the population living in Switzerland, future research should be translated into other languages, such as Italian, Spanish and Portuguese. Furthermore, the high education level may be considered another limitation. This can be addressed in future research involving microalgae-based foods by using a different recruiting method.

5. Conclusions

This study identified and profiled six segments related to microalgae perception and attitudes: 'microalgae supporters and health eaters', 'innovative and adventurous', 'aware and open-minded', 'uninformed but susceptible', 'conservatives' and 'microalgae avoiders and traditional'. Four already have a more positive attitude towards microalgae and can be considered the primary target groups for microalgae-based foods. In general, segments composed of consumers with low food neophobia, low food technology neophobia and lower interest in familiar/traditional foods are more open to accepting microalgae-based foods. Furthermore, these more open segments also believe that excess meat production and consumption negatively affect sustainability. The present study also illuminates the current low frequency of consumption of microalgae-based foods in Switzerland and presents some strategies to reach different consumer segments, such as offering processed and/or ready-to-eat microalgal-based foods containing no artificial ingredients and providing information on microalgae benefits. These findings can help the food industry and marketing sectors, which can result in higher microalgae-based food demand.

CRediT authorship contribution statement

Bárbara Franco Lucas: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. **Thomas A. Brunner:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Visualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Ethical statement

The study neither presented risks to participants nor dealt with sensitive topics. It was carried out in accordance with the Guidelines for Ethical Conduct in Research from Bern University of Applied Sciences (reference n° EAB2022-020). Participants acknowledged an informed consent statement before starting the survey. They were also informed of the possibility of dropping out of the study at any time without providing a reason.

References

[1] FAO, IFAD, UNICEF, WFP, WHO, The state of food security and nutrition in the world 2020, in: Transforming Food Systems for Affordable Healthy Diets, FAO, Rome, 2020, https://doi.org/10.4060/ca9692en.

[2] K. Henn, S.B. Olsen, H. Goddyn, W.L.P. Bredie, Willingness to replace animal-based products with pulses among consumers in different European countries, Food Res. Int. 157 (2022) 111403, https://doi.org/10.1016/j.foodres.2022.111403.

[3] B.F. Lucas, J.A.V. Costa, T.A. Brunner, Attitudes of consumers toward Spirulina and açaí and their use as a food ingredient, LWT 178 (2023) 114600, https://doi.org/10.1016/j.lwt.2023.114600.

[4] M.C. Onwezen, E.P. Bouwman, M.J. Reinders, H. Dagevos, A systematic review on consumer acceptance of alternative proteins: pulses, algae, insects, plant-based meat alternatives, and cultured meat, Appetite 159 (2021) 105058, https://doi.org/10.1016/j.appet.2020.105058.

[5] T. Lafarga, G. Acién, Microalgae for the food industry: from biomass production to the development of functional foods, Foods 11 (2022) 765, https://doi.org/10.3390/foods11050765.

[6] N. Maehle, F. Skjeret, Microalgae-based food: purchase intentions and willingness to pay, Future Foods 6 (2022) 100205, https://doi.org/10.1016/j.fufo.2022.100205.

[7] P.L. Show, Global market and economic analysis of microalgae technology: status and perspectives, Bioresour. Technol. 357 (2022) 127329, https://doi.org/10.1016/j.biortech.2022.127329.

[8] A. Ahmad, S.S. Ashraf, Sustainable food and feed sources from microalgae: food security and the circular bioeconomy, Algal Res. 74 (2023) 103185, https://doi.org/10.1016/j.algal.2023.103185.

[9] M.M. Nakamoto, M. Assis, J.G.O. Filho, A.R.C. Braga, Spirulina application in food packaging: gaps of knowledge and future trends, Trends Food Sci. Technol. 133 (2023) (2023) 138–147, https://doi.org/10.1016/j.tifs.2023.02.001.

[10] A.R.C. Braga, M.C. Nunes, A. Raymundo, The experimental development of emulsions enriched and stabilized by recovering matter from Spirulina biomass: valorization of residue into a sustainable protein source, Molecules 28 (2023) 6179, https://doi.org/10.3390/molecules28176179.

[11] M.P. Caporgno, L. Böcker, C. Müssner, E. Stirnemann, I. Haberkorn, H. Adelmann, S. Handschin, E.J. Windhab, A. Mathys, Extruded meat analogues based on yellow, heterotrophically cultivated Auxenochlorella protothecoides microalgae, Innov. Food Sci. Emerg. Technol. 59 (2020) 102275, https://doi.org/10.1016/j.ifset.2019.102275.

[12] S. Grahl, M. Strack, R. Weinrich, D. Mörlein, Consumer-oriented product development: the conceptualization of novel food products based on spirulina (Arthrospira platensis) and resulting consumer expectations, J. Food Qual. 2018 (2018) 1–11, https://doi.org/10.1155/2018/1919482.

[13] J. Ampofo, L. Abbey, Microalgae: bioactive composition, health benefits, safety and prospects as potential high-value ingredients for the functional food industry, Foods 11 (2022) 1744, https://doi.org/10.3390/foods11121744.

[14] Y. Wang, S.M. Tibbetts, P.J. McGinn, Microalgae as sources of high-quality protein for human food and protein supplements, Foods 10 (2021) 3002, https://doi.org/10.3390/foods10123002.

[15] M.C.J. Caniëls, W. Lambrechts, J. Platje, A. Motylska-Kuźma, B. Fortuński, Impressing my friends: the role of social value in green purchasing attitude for youthful consumers, J. Clean. Prod. 303 (2021) 126993, https://doi.org/10.1016/j.jclepro.2021.126993.

[16] R. Brečić, Ž. Mesić, M. Cerjak, Importance of intrinsic and extrinsic quality food characteristics by different consumer segments, Br. Food J. 119 (2017) 845–862, https://doi.org/10.1108/BFJ-06-2016-0284.

[17] A. Knaapila, F. Michel, K. Jouppila, T. Sontag-Strohm, V. Piironen, Millennials' consumption of and attitudes toward meat and plant-based meat alternatives by consumer segment in Finland, Foods 11 (2022) 456, https://doi.org/10.3390/foods11030456.

[18] M. Sarstedt, E. Mooi, Cluster analysis, in: M. Sarstedt, E. Mooi (Eds.), A Concise Guide to Market Research, Springer, Berlin, Heidelberg, 2019, pp. 301–354, https://doi.org/10.1007/978-3-662-56707-4_9.

[19] B.F. Lucas, F. Götze, J.A.V. Costa, T.A. Brunner, Consumer perception toward "superfoods": a segmentation study, J. Int. Food Agribus. Mark. 2022 (2022), https://doi.org/10.1080/08974438.2022.2044955.

[20] I. Moons, C. Barbarossa, P.D. Pelsmacker, The determinants of the adoption intention of eco-friendly functional food in different market segments, Ecol. Econ. 151 (2018) 151–161, https://doi.org/10.1016/j.ecolecon.2018.05.012.

[21] L. Malek, W.J. Umberger, Protein source matters: understanding consumer segments with distinct preferences for alternative proteins, Future Foods 7 (2023) 100220, https://doi.org/10.1016/j.fufo.2023.100220.

[22] T. Lafarga, R. Rodríguez-Bermúdez, A. Morillas-España, S. Villaró, M. García-Vaquero, L. Morán, A. Sánchez-Zurano, C.V. González-López, F.G. Acién-Fernández, Consumer knowledge and attitudes towards microalgae as food: the case of Spain, Algal Res. 54 (2021) 102174, https://doi.org/10.1016/j.algal.2020.102174.

[23] R. Weinrich, O. Elshiewy, A cross-country analysis of how food-related lifestyles impact consumers' attitudes towards microalgae consumption, Algal Res. 70 (2023) 102999, https://doi.org/10.1016/j.algal.2023.102999.

[24] World Intellectual Property Organization (WIPO), Global Innovation Index 2021: executive summary. 14th ed. https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2021_exec.pdf#page=6, 2021.

[25] Inossuisse, Plant-based meat with further improved taste and texture. https://www.innosuisse.ch/inno/en/home/success-stories/funding-examples/innovation-projects/planted.html, 2022.

[26] B.F. Lucas, J.A.V. Costa, T.A. Brunner, How information on superfoods changes consumers' attitudes: an explorative survey study, Foods 11 (2022) 1863, https://doi.org/10.3390/foods11131863.

[27] B.F. Lucas, J.A.V. Costa, T.A. Brunner, Superfoods: drivers for consumption, J. Food Prod. Mark. 27 (2021) 1–9, https://doi.org/10.1080/10454446.2020.1869133.

[28] J.A. Krosnick, A.L. Holbrook, M.K. Berent, R.T. Carson, W.M. Hanemann, R.J. Kopp, R.C. Mitchell, S. Presser, P.A. Ruud, V.K. Smith, W.R. Moody, M.C. Green, M. Conaway, The impact of "no opinion" response options on data quality: non-attitude reduction or an invitation to satisfice? Public Opin. Q. 66 (2002) 371–403, https://doi.org/10.1086/341394.

[29] M. Niva, A. Vainio, Towards more environmentally sustainable diets? Changes in the consumption of beef and plant- and insect-based protein products in consumer groups in Finland, Meat Sci. 182 (2021) 108635, https://doi.org/10.1016/j.meatsci.2021.108635.

[30] T.A. Brunner, M. Delley, C. Denkel, Consumers' attitudes and change of attitude toward 3D-printed food, Food Qual. Prefer. 68 (2018) 389–396, https://doi.org/10.1016/j.foodqual.2017.12.010.

[31] M. Delley, T.A. Brunner, Breakfast eating patterns and drivers of a healthy breakfast composition, Appetite 137 (2019) 90–98, https://doi.org/10.1016/j.appet.2019.02.006.

[32] P. Pliner, K. Hobden, Development of a scale to measure the trait of food neophobia in humans, Appetite 19 (1992) 105–120, https://doi.org/10.1016/0195-6663(92)90014-W.

[33] D.N. Cox, G. Evans, Construction and validation of a psychometric scale to measure consumers' fears of novel food technologies: the food technology neophobia scale, Food Qual. Prefer. 19 (2008) 704–710, https://doi.org/10.1016/j.foodqual.2008.04.005.

[34] K. Roininen, L. Lähteenmäki, H. Tuorila, Quantification of consumer attitudes to health and hedonic characteristics of foods, Appetite 33 (1999) 71–88, https://doi.org/10.1006/appe.1999.0232.

[35] K. Brunsø, K. Grunert, Development and testing of a cross-culturally valid instrument: food-related life style, Adv. Consum. Res. 22 (1995) 475–480.

[36] R. Bell, D.W. Marshall, The construct of food involvement in behavioral research: scale development and validation, Appetite 40 (3) (2003) 235–244, https://doi.org/10.1016/S0195-6663(03)00009-6.

[37] M. Lindeman, M. Väänänen, Measurement of ethical food choice motives, Appetite 34 (2000) 55–59, https://doi.org/10.1006/appe.1999.0293.

[38] A. Steptoe, T.M. Pollard, J. Wardle, Development of a measure of the motives underlying the selection of food: the food choice questionnaire, Appetite 25 (1995) 267–284, https://doi.org/10.1006/appe.1995.0061.

[39] M. Dickson-Spillmann, M. Siegrist, C. Keller, Development and validation of a short, consumer-oriented nutrition knowledge questionnaire, Appetite 56 (3) (2011) 617–620, https://doi.org/10.1016/j.appet.2011.01.034.

[40] V. Balijepally, G. Mangalaraj, K. Iyengar, Are we wielding this hammer correctly? A reflective review of the application of cluster analysis in information systems research, J. Assoc. Inf. Syst. 12 (5) (2011) 375–413, https://doi.org/10.17705/1jais.00266.

[41] B.F. Lucas, M.G. Morais, T.D. Santos, J.A.V. Costa, Spirulina for snack enrichment: nutritional, physical and sensory evaluations, LWT 90 (2018) 270–276, https://doi.org/10.1016/j.lwt.2017.12.032.

[42] N. Palmieri, M.B. Forleo, The potential of edible seaweed within the western diet. A segmentation of Italian consumers, Int. J. Gastron. Food Sci. 20 (2020) 100202, https://doi.org/10.1016/j.ijgfs.2020.100202.

[43] R. Weinrich, B. Gassler, Beyond classical van Westendorp: assessing price sensitivity for variants of algae-based meat substitutes, J. Retailing Consum. Serv. 63 (2021) 102719, https://doi.org/10.1016/j.jretconser.2021.102719.

[44] J.J. Duckworth, M. Randle, L.S. McGale, A. Jones, B. Doherty, J.C.G. Halford, P. Christiansen, Do front-of-pack 'green labels' increase sustainable food choice and willingness-to-pay in U.K. consumers? J. Clean. Prod. 371 (2022) 133466 https://doi.org/10.1016/j.jclepro.2022.133466.

[45] Federal Statistical Office, Composition of the foreign population. https://www.bfs.admin.ch/bfs/en/home/statistics/population/migration-integration/foreign/composition.html, 2022 (accessed 30 May 2023).