



Factors influencing the willingness to purchase and consume microalgae-based foods: An exploratory consumer study

Bárbara Franco Lucas^{*}, Thomas A. Brunner

Food Science and Management, School of Agricultural, Forest and Food Sciences (HAFL), Bern University of Applied Sciences (BFH), Länggasse 85, 3052, Zollikofen, Switzerland

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ABSTRACT

The aim of this study was to identify factors that influence consumers' willingness to purchase and consume microalgae-based foods. Data from an online survey (n = 583) conducted in Switzerland were analysed using multiple linear regression. The model revealed that the consumers interested in purchasing and consuming microalgae-based foods had low scepticism towards new food technologies, believed that high meat production and consumption negatively impact sustainability and were interested in protecting the environment. The results contribute to the existing literature and assist the food industry and the gastronomy sector in reaching target consumer groups.

1. Introduction

The population is increasing and is expected to reach 9.7 billion in 2050 (United Nations, 2019). Therefore, innovative and sustainable ideas for meeting the population's protein needs are needed. Microalgae are photosynthetic organisms found in the environment that can convert CO₂ and sunlight into biomass. Certain microalgae biomass contains high amounts of proteins with high digestibility, all essential amino acids besides other compounds, including vitamins, carotenoids and phycocyanin. These microalgae can be used as ingredients in a range of foods such as snack bars, yoghurt, and pasta, providing natural colour and nutritional improvement (Lucas et al., 2019; Villaró-Cos et al., 2024). In addition, recent research has confirmed the potential of microalgae as a raw material in the development of meat substitutes with suitable physicochemical properties (Caporgno et al., 2020; De Gol et al., 2023). Many commercial products are already available in supermarkets as well as microalgae powder. These are produced from edible microalgae that are recognised as GRAS (generally recognised as safe) by the FDA (Food and Drug Administration) and by other authorities on food safety (Lafarga, 2019; Gao et al., 2024; Villaró-Cos et al., 2024).

Cultivating this organism does not require arable land and demands less water than is required to produce traditional protein sources. Reduced GHG emissions can also be observed by cultivating microalgae (Yang et al., 2024). Thus, these organisms can play a significant role in

the future of sustainable food production (Gohara-Beirigo et al., 2022; Lafarga and Acién, 2022). According to Show (2022), food security and environmental issues are factors that can increase consumer interest in algae and microalgae. This is important because a diet shift to a more sustainable one (reducing animal-origin foods) is directly related to climate change mitigation (Perez-Cueto et al., 2022).

Studying consumer perceptions is important in launching a product with success in the market, as many variables influence food acceptance. Several socio-psychological consumer characteristics influence attitudes and decision-making (Ran et al., 2022). Recently, Lucas and Brunner (2024) revealed six different segments of consumers regarding attitudes towards microalgae as food in Switzerland and highlighted the segment 'microalgae supporters and health eaters' as more prone to accept and consume these foods. Weinrich and Elshiewy (2023) studied the attitudes of consumers in France, the Netherlands and Germany towards microalgae as food. They reported that consumers with a positive attitude towards microalgae were open to trying novel foods and recipes and interested in organic foods. Maehle and Skjeret (2022) examined consumer attitudes towards bread and beer that used microalgae as an ingredient and purchase intention and willingness to pay for these foods. The authors reported that a positive attitude towards these foods will positively influence purchase intentions.

Van der Stricht et al. (2023) investigated the influence of front-of-pack labels on consumers' willingness to buy pasta-containing microalgae. The authors reported that labels such as Nutri-Score,

^{*} Corresponding author.

E-mail addresses: barbara.franco@bfh.ch (B. Franco Lucas), thomas.brunner@bfh.ch (T.A. Brunner).

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Table 1
Sample characteristics.

	% Sample		% Sample
Sex^a		Responsible for buying food	
Female	55.6	Yes	89.6
Male	44.4	No	10.4
Age groups		Responsible for cooking	
18–39 years old	21.2	Yes	84.6
40–59 years old	40.3	No	15.4
60–older	38.5		
Education		Eating diet	
None, mandatory	2.7	Omnivore	57.0
Secondary level (vocational education)	12.5	Flexitarian	33.6
Secondary level (general education)	5.4	Vegetarian	6.7
Tertiary degree (higher vocational education)	31.1	Vegan	2.7
Tertiary degree (Applied school/University)	48.3		
Employment status			
Full-time (≥90%)	32.9		
Part-time (50–89%)	26.5		
Part-time (<50%)	9.4		
Not working	31.2		

Note.

^a The Swiss population in 2022 was composed of 50.3 % of females and 49.7% of males (Federal Statistical Office, 2023).

organic and vegan positively influenced the willingness to pay for this food. Wassmann et al. (2024) reported that Singaporean consumers' willingness to buy microalgae meat substitutes was positively related to sustainability and health concerns. However, in some cases, consumers expected alternative foods made from algae to be less tasty compared to animal-derived options (Michel et al., 2021).

Despite the great interest and large number of studies on the development of foods enriched with microalgae (Gohara-Beirigo et al., 2022; Lafarga, 2019; Lucas et al., 2018) and consumer perception and attitudes towards plant-based foods (Perez-Cueto et al., 2022; Rizzo et al., 2023), only a few studies have evaluated consumer perceptions towards and willingness to purchase microalgae-based foods (Lafarga et al., 2021; Lucas et al., 2023; Maehle and Skjeret, 2022; Van der Stricht et al., 2023; Wassmann et al., 2024; Weinrich and Elshiewy, 2023). This topic was not deeply explored in Switzerland. Therefore, this exploratory study aimed to add to the limited literature by identifying factors influencing consumers' willingness to purchase and consume microalgae. The study was conducted in Switzerland because it is an innovative country with numerous products made from alternative proteins available on the market (Michel et al., 2021). Producers, marketers, the gastronomic sectors, and policymakers could use the results to set strategies to increase microalgae-based food production and consumption worldwide.

2. Methods

2.1. Survey and participants

Data were collected in Switzerland from January to February 2023 (Lucas and Brunner, 2024). A flyer containing a link to an online survey was sent out by post to randomly selected postal codes in the German and French-speaking parts of Switzerland. The participants had to agree to participate in the study by filling out an informed consent form before initiating the survey. Data were cleaned and cases that failed in the instructional manipulation check (control question) and the consistency check were removed, resulting in a final sample of $n = 583$. The sample characteristics are displayed in Table 1.

2.2. Measures

In the first part of the survey, attitudes towards microalgae using a semantic differential scale and questions on the benefits of these foods were queried (Lucas and Brunner, 2024). Participants also answered questions regarding the presentation of meat substitutes that they would

be more prone to consume if they were developed with microalgae (Table 2). Meat substitutes were chosen for evaluation owing to the current concern about reducing meat consumption worldwide. The participants had to rate examples of microalgae-based foods using a 6-point scale from 1 = very unlikely to 6 = very likely (Table 2).

Question: "How likely are the following microalgae-based products to be a regular part of your diet if they look similar to meat?"

Next, an exploratory factor analysis was performed with these eight items using the principal components method. One single component explaining 68% of the variance was obtained (Cronbach's $\alpha = 0.93$). The scree plot confirmed the presence of one component (Field, 2013). This was represented as item 1 named 'willingness to consume microalgae-based meat substitutes' in Table 3.

Table 2

Mean scores for the presentation form of meat substitutes.

Items	Mean	SD
Minced	3.27	1.75
Burger	3.11	1.73
Nuggets	2.96	1.69
Balls	2.94	1.68
Marinated pieces	2.79	1.62
Sausage	2.61	1.58
Filet pieces	2.55	1.56
Sliced cold	2.41	1.51

Note: *Scale measurement ranging from 1 = very unlikely to 6 = very likely.

Table 3

Descriptive statistics of the items used to create the dependent variable.

Items	Mean	SD
1. Willingness to consume microalgae-based meat substitutes ^{a b}	2.83	1.35
2. I can imagine buying and consuming microalgae/microalgae-based foods regularly**	4.05	1.30
3. I would be willing to pay a little more for microalgae/microalgae-based foods than for vegetables**	3.33	1.38
4. I would be willing to pay a little more for microalgae-based meat substitutes than for meat**	3.12	1.54
Dependent Variable: Willingness to purchase and consume microalgae-based foods	3.33	1.15

Note.

**Scale measurement ranging from 1 = strongly disagree to 6 = strongly agree.

** Three items from the scale position on microalgae (Lucas and Brunner, 2024).

^a Scale measurement ranging from 1 = very unlikely to 6 = very likely.

^b Mean of the scores from the eight presentation forms queried.

Table 4
Scales and items used in the regression analyses and Cronbach's α .

	Parameters/scales	Example of an item	Number of items	Cronbach's α
Dependent variable	Willingness to purchase and consume microalgae-based foods	(See Table 3)	4	0.84
Independent variables	1. Sustainability* (Niva and Vainio, 2021)	If people in the world ate less meat, there would be enough food for everybody	3	0.85
	2. Cooking creativity (Brunner et al., 2018)	Cooking allows me to express my creativity	3	0.86
	3. Self-reported health status (Delley and Brunner, 2019)	I am very physically active	3	0.84
	4. Food technology neophobia (Cox and Evans, 2008)	There are plenty of tasty foods around so we don't need to use new food technologies to produce more	4	0.83
	5. General health interest (Roininen et al., 1999)	I am very particular about the healthiness of food I eat	3	0.78
	6. Price/quality relation (Brunso and Grunert, 1995)	I compare the prices between product variants in order to get the best value for money	3	0.66
	7. Food involvement (Bell and Marshall, 2003)	Talking about what I ate or am going to eat is something I like to do	4	0.64
	8. Environmental protection [†] (Lindeman and Väänänen, 2000)	Has been produced in a way which has not shaken the balance of nature	3	0.88
	9. Sensory appeal [†] (Step toe et al., 1995)	Tastes good	4	0.76
	10. Natural content [†] (Step toe et al., 1995)	Contains no additives	3	0.88
	11. Familiarity [†] (Step toe et al., 1995)	Is what I usually eat	3	0.74
	12. Mood [†] (Step toe et al., 1995)	Makes me feel good	3	0.62

Legend: [†]It is important to me that the food I eat on a typical day: Note: Scales ranging from 1 = strongly disagree to 6 = strongly agree. *Sustainability related to meat production and consumption.

The mean score for the four items displayed in Table 3 was used to create the dependent variable 'willingness to purchase and consume microalgae-based foods'. This variable was applied in the regression model (please see Table 4).

In the next part of the questionnaire, scales related to behavioural patterns (Table 4) that previous research revealed to be related to consumers' interest in healthier and more sustainable foods were included in the survey (Lucas et al., 2021; Lucas and Brunner, 2024; Maehle and Skjeret, 2022; Niva and Vainio, 2021), and sociodemographic questions (sex, age, education and employment) were queried at the end. These constructs were used as independent variables in the regression model (Table 4).

2.3. Statistical analyses

The statistical analyses were performed using IBM SPSS Statistics (v.28). Cronbach's α was used to check the reliability of the scales. Multiple linear regression analysis was applied to analyse which of the 16 predictors (the independent variables displayed in Table 4 and sex, age, education and employment) exert influence on the willingness to purchase and consume microalgae-based foods. The correlation matrix and collinearity diagnostics indicated no cause for concern regarding multicollinearity (Field, 2013). Variance inflation factors were close to 1, and the tolerance statistics were well above 0.2. The analysis of variance revealed that the model was a significant fit to the data overall.

Table 5

Multiple linear regression analysis predicting the respondents' willingness to purchase and consume microalgae-based foods.

Variable	B	SE (B)	β	p
Constant	2.38	0.22		<0.001
Sustainability*	0.40	0.03	0.48	<0.001
Food technology neophobia	-0.38	0.03	-0.36	<0.001
Environmental protection	0.14	0.04	0.11	<0.001

$R^2 = 0.57$. Legend: *Sustainability related to meat production and consumption. B: Unstandardized coefficient B; SE (B): Coefficients Std. Error; β : Standardized Coefficients Beta; p: significance. N = 580 due to three missing values in the question 'sex'. Note: Sustainability related to meat production and consumption construct (M = 4.01; SD = 1.38); Food technology neophobia (M = 3.48; SD = 1.11); Environmental protection (M = 4.83; SD = 0.88).

Predictors with a p-value <0.05 were considered relevant and included in the model (Table 5).

3. Results

Of the 16 predictors evaluated, only three emerged as significant and exerting an influence on consumers' willingness to purchase and consume microalgal-based foods. Table 5 shows the predictors that significantly contributed to the regression model ($p < 0.05$), explaining 57% of the variance.

The strongest predictors ($p < 0.001$) for the model were *sustainability* (perception related to reductions in meat production and consumption) and *food technology neophobia*. Thus, the higher the perceived *sustainability related to the reductions in meat production and consumption*, the higher the willingness to purchase and consume microalgal-based foods. The model also revealed that the lower the *phobia towards new technologies used to produce food*, the higher the willingness to purchase and consume foods with added microalgae. Interest in environmental protection was the third significant predictor and a driver of the intention to buy and eat food incorporated with microalgae. As expected, the higher the interest in *environmental protection*, the higher the intention to buy and eat these foods.

4. Discussion

4.1. General findings

Microalgae are considered one of the most promising sustainable sources of protein that can be applied in a range of foods, with advantages related to their nutritional composition such as proteins and high-value bioactive compounds such as carotenoids (Lucas et al., 2018). For this reason, this study is relevant and adds valuable information to the current literature on consumer behaviour regarding microalgae.

Regarding the type of meat substitutes presented, 'minced' and 'burger' obtained higher scores and would be most appreciated by the consumers if they looked similar to meat (Table 2). Michel et al. (2021) revealed that European consumers would expect algae burgers to be healthier and environmentally friendly but less tasty than the animal-based option. According to Palmieri and Forleo (2020), developing the culinary and gastronomic potential of seaweed can increase the consumption of these foods. This could also be interesting for

microalgae, and the examples of meat substitutes with higher scores in this study could be considered examples of dishes with great potential.

The mean scores displayed in Table 3 also highlight that despite consumers appearing to be open to buying and consuming foods added with microalgae regularly (mean score, >4.0), they seemed to be not that open to investing more money in these foods compared with conventional ones. When asked if they would be willing to pay more for these foods than for vegetables or meat (Table 3), the mean score was lower than 3.5. This outcome was expected in a sample with a large proportion of meat eaters (omnivores and flexitarians, accounting for >90%). Thus, the findings highlight that the prices of microalgal-based foods should be competitive with plant-based options and meat to attract consumers.

4.2. Regression analysis results

The regression results in the present study revealed the factors that influence the adoption of microalgal-based foods among Swiss consumers. The *sustainability* scale assessed the 'perceived environmental and social sustainability and ethicalness of meat production and consumption' (Niva and Vainio, 2021). Thus, the higher the scores on this scale, the stronger the respondents' perception that the production and consumption of meat in excess negatively affects sustainability. Based on these findings, consumers who are aware of the disadvantages of animal meat to sustainability would be more willing to buy and consume microalgae-based foods.

The latest research has confirmed the importance of this attribute. Weinrich and Elshiewy (2019) found that European consumers with negative attitudes towards meat based on ethical concerns were more prone to accept microalgae-based meat substitutes. Wassmann et al. (2024) revealed sustainability concerns as a strong predictor of willingness to buy microalgae-based foods. Based on the findings, improving consumers' knowledge of sustainability and issues related to excess meat production and consumption could boost their willingness to buy this innovative alternative protein. However, previous research has also reported that even with a large proportion of people being aware of the need to buy foods with low climate impact, a smaller proportion buy sustainable foods (Ran et al., 2022; Sajn, 2020). Thus, other factors that also influence consumer behaviour such as price should be taken into account (Weinrich and Elshiewy, 2023).

Consumers' scepticism towards certain food technologies is a barrier to improving diets to more sustainable ones (Giacalone and Jaeger, 2023). In the present study, the respondents who were more open to purchasing and including microalgae in their diet were more open to trying high-tech food products and more likely to believe in the benefits of new food technologies. Thus, our findings suggest that the microalgal food industry can adopt new technologies and approaches to produce microalgae-based foods, as open consumers tend to have a low phobia towards new technologies. However, the present findings cannot be generalized to all novel food technologies, as consumer perception varies according to the novel technology applied to produce more sustainable foods (Giacalone and Jaeger, 2023).

As expected, interest in environmental protection was a driver of willingness to buy and eat microalgal foods. Recently, the study of Van der Stricht et al. (2024) revealed that European consumers with greater environmental concerns were also more willing to try foods with added microalgae proteins. Maehle and Skjeret (2022) reported environmental concern as significantly and positively related to consumers' attitudes and purchase intentions towards microalgae-based food. Wassmann et al. (2024) revealed that environmental friendliness is one of the most convincing attributes of microalgae-based foods. Providing information to consumers about the sustainability of a particular food is of great importance and may lead to sustainable food choices and behavioural change (Groth et al., 2023).

4.3. Limitations

Despite these interesting findings, the present study has limitations. Results might vary between countries, depending on the culture. Previous research has found heterogeneity in the attitudes of European countries towards microalgae as food (Weinrich and Elshiewy, 2023). Recently, Giacalone and Jaeger (2023) found that Indian consumers were more open to accepting novel food technologies than consumers from Western countries. Thus, our findings can not be generalized. A second limitation is that the link to the survey was sent out to the German and French-speaking parts of Switzerland which accounts for the greatest share of the population, excluding the Italian-speaking part. To overcome this limitation, the next surveys should be translated into Italian, and the flyers sent to Italian cantons.

Furthermore, the present study did not address differences between consumers with different diets. Thus, we suggest that future studies address differences between omnivores, flexitarians, vegetarians and vegans regarding their attitudes towards the use of microalgae in food.

Despite we have revealed some examples of microalgae-based meat substitutes and the scores given by the respondents, these presentation forms were selected based on the plant-based products that already exist in the market. Thus, we suggest for future research to apply qualitative research to gain new insights such as other foods not mentioned in the present study that consumers may be interested in consuming. In addition, other plant proteins are often required to be blended with microalgae in meat substitute production. Thus, the ingredient list and other factors such as clean labels should also be considered in further studies.

Knowing how much more the consumer would be willing to pay can also support the development of microalgal foods in the market. However, in the present study, this was not accessed and can be seen as a limitation, being interesting for further research.

5. Conclusion

Compared to meat production, microalgae can be considered a sustainable option to be part of the global population diet. This study investigated consumers' willingness to purchase and consume microalgae through an online survey conducted in Switzerland. The study revealed consumers' willingness to buy and consume microalgae-based foods and some meat substitutes that Swiss consumers would be more prone to accept if they contained microalgae in the formulation. In the regression model, three variables showed high predictive power. In summary, the study revealed that the participants with greater interest in purchasing and consuming microalgae as food had 1) a perception that excess meat production and consumption negatively affect sustainability, 2) low food technology neophobia and 3) an interest in environmentally friendly foods. These findings might shed light on the future of microalgae-based food marketing and commercialisation and are useful for the gastronomic sector.

Implications for gastronomy

Microalgae such as *Spirulina* and *Chlorella* are promising ingredients that have high contents of protein and bioactive compounds that can be applied in a wide range of foods. In this study, we investigated consumers' willingness to purchase and consume microalgae-based foods and found that consumers who were more open to these foods were also interested in animal production sustainability and protecting the environment. Based on these findings, we suggest that marketing of these products should focus on the characteristics of microalgae being more sustainable than meat and environmentally friendly. Furthermore, the application of new food technologies can also be considered to develop high-tech microalgal products, as a higher level of willingness to purchase and consume these products is related to consumers' low food technology neophobia. We also presented examples of meat substitutes that consumers would be more willing to adopt in their diets if they

looked similar to meat. This information can add to the limited literature available and support the food industry and gastronomy sector in reaching microalgal consumers.

Ethical statement

The present study was conducted following the guidelines of Ethical Conduct in Research of the Bern University of Applied Sciences. The participants provided informed consent, and an affirmative reply was required to enter the survey. They could withdraw from the survey at any time without giving a reason.

CRedit authorship contribution statement

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

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.

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