

Microalgae-based food: Purchase intentions and willingness to pay

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ABSTRACT

Consumer acceptance is pivotal for the success of new foods, and it is therefore necessary to understand the determinants influencing consumers' behaviour for microalgae-based food. The current study explores the influence of various factors on consumers' attitude, purchase intention and willingness to pay for two microalgae-based products (bread and beer). An online survey with a consumer panel ($N = 1,011$) was conducted, and a structural equation modelling procedure was implemented. The results indicate that environmental concern and subjective norms (i.e., social norms on microalgae-based food) have significant positive effect on consumers' attitude and purchase intentions towards microalgae-based food. Purchase intentions, attitude towards innovation in food and subjective norms positively and highly significantly impact the willingness to pay for microalgae-based food. Thus, microalgae-based food appeals to the environmentally engaged and innovative consumers. Moreover, the opinions of others play an important role in the acceptance of the microalgae-based food. This study contributes to the emerging stream of literature on microalgae-based food. Understanding which factors influence the purchase behaviour for this food is highly important for its market success. The study provides evidence-based input for practitioners in their efforts to evaluate consumer interest for microalgae-based food and develop effective marketing strategies for its further promotion.

1. Introduction

With growing world population, there is a need for new sources of sustainable protein supply (Leite Milião et al., 2022; Nguyen et al., 2022). Microalgae – microscopic photosynthetic organisms found in both marine and freshwater environments – can be one of such sources. It contains high amounts of omega-3 fatty acids providing beneficial health effects such as maintenance of normal cardiac function, normal brain function, and normal vision (Georgiou et al., 2014; von Schacky, 2021; von Schacky and Harris, 2007). In addition, compared to conventional food, microalgae-based foods have a more environmentally friendly low-carbon profile as microalgae can be produced on non-arable land with a high production rate per square metre and thus reduce expansion of food production in agricultural land (Ferreira de Oliveira and Pavesi Arisseto Bragotto, 2022; Weinrich and Elshiewy, 2019).

Microalgae thus shows high potential as a naturally functional ingredient (Plaza et al., 2008) providing both health and environmental benefits. In the recent years, consumers have demonstrated a growing interest towards functional foods (Miroso and Mangan-Walker, 2018; Song and Im, 2018; Nielsen, 2015), i.e., foods containing bioactive compounds with a physiologically proven prevention and treatment

of chronic diseases (Martirosyan and Singh, 2015). Combined with an increasing demand for algae-based products (Wells et al., 2017), this opens new possibilities for innovative use of microalgae in food production. Microalgae has already been used in various food products, e.g., pastas, snacks, biscuits, candies, gums, yoghurts, drinks, and bread (Batista et al., 2012; Fradique et al., 2010; Grahl et al., 2020). Nevertheless, changing consumers' dietary preferences can be a difficult task, and more research is necessary to understand consumer perceptions of microalgae-based foods.

Consumer acceptance is pivotal for the success of new food (Motoki et al., 2021; Shamal and Mohan, 2017), and there are several potential challenges related to microalgae-based food. Despite improving nutritional characteristics, microalgae can change the colour and flavour of food (Coleman et al., 2022; Mohamed et al., 2013). Consumers thus may be sceptical to microalgae-based food due to potential negative associations (e.g., perceived bad taste). For example, research (Michel et al., 2021) shows that consumers expect burgers with algae protein to be less tasty than beef burger. Sensory preferences play an important role in food acceptability (de Beukelaar et al., 2019). Sensory characteristics such as flavour can be even more crucial for functional foods than for regular ones as functional foods usually have higher prices, and to compensate consumers want excellent flavour (Barrios et al., 2008).

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Moreover, consumer knowledge about microalgae is rather limited and they are not fully aware about its health and environmental benefits (Lafarga et al., 2021). In addition, the literature (Kraus, 2015) shows that consumers sometimes have doubts about the positive health effects of functional foods due to the lack of understanding of ‘functional food’ concept. People tend to accept novel foods easier if they bring tangible consumer benefits (Frewer et al., 2003); however, health claims can be considered as “credence characteristics” that cannot directly be experienced by consumers. Moreover, consumers are not willing to trade off key product qualities (e.g., good taste) for more socially acceptable attributes (e.g., higher sustainability) (Auger et al., 2008). Based on the complexity related to microalgae food perceptions, it is necessary to understand the determinants of consumers’ behaviour towards microalgae-based food.

To address this need, the current study explores the influence of various factors on the purchase behaviour for two microalgae-based products (bread and beer). In particular, we consider how attitude towards innovation in food, neophobia, general health interest, environmental concern, and subjective norms influence consumers’ attitude, purchase intention and willingness to pay for these food products. An online survey with a consumer panel was conducted. The results indicate that microalgae-based food appeals to the environmentally engaged and innovative consumers. Moreover, the opinions of others (subjective norms) play an important role in the further acceptance of the microalgae-based food.

The remaining part of the paper is organised as follows. Section 2 focuses on the conceptual model and hypotheses, and Section 3 presents the methodological approach. In Section 4, the main results are presented. Section 5 provides the discussion of findings and the main theoretical and practical implications.

2. Conceptual model and hypothesis development

Food choices are often extremely complex. Food is directly ingested into the human body, which makes the relationship between consumers and food especially intimate. Moreover, food is usually eaten in a social context where consumers are influenced by other people (Frostling-Henningson et al., 2014; Salmivaara et al., 2021). Consumer’s choice for or against sustainable food can also be framed as a social dilemma (Olsen and Tuu, 2021; van Doorn and Verhoef, 2011). Consumers need to balance egoistic motivations such as food quality and health considerations, up-against altruistic motivations such as better environment and reduced climate emissions (Birch et al., 2018). Food choices reflect therefore compromises in everyday life and are influenced by various factors.

To explain the relationship between attitudes and behaviour, the current study takes a starting point in the theory of reasoned action (Ajzen and Fishbein, 1980), which derived from research in social psychology, persuasion models, and attitude theories. This theory has been extensively tested in numerous studies across many different types of products and is one of the most established theories used to predict consumer behaviour. It has also been widely used in predicting sustainable food consumption (e.g., Kumar et al., 2022). The theory of reasoned action states that a person’s intention to perform a behaviour is the main predictor of whether he actually performs that behaviour. This intention in its turn is a result of a belief that performing the behaviour will lead to a specific outcome. Additionally, the normative component (i.e., social norms surrounding the act) contributes to whether the person will actually perform the behaviour. If people evaluate the suggested behaviour as positive (attitude) and if they think others want them to perform the behaviour (subjective norm), this results in a higher intention, and they are more likely to perform the behaviour. Significant positive relationship between subjective norms and consumers’ purchase intention has also been demonstrated in several studies on sustainable food consumption (Chen, 2007; Dean et al.,

2008; Kumar et al., 2022). Based on this reasoning, we hypothesize the following:

- Hypothesis 1: Positive attitude towards microalgae-based food will positively influence purchase intentions for this food.
- Hypothesis 2: Favourable subjective norms towards microalgae-based food will positively influence purchase intentions for this food.

The previous literature also demonstrates that attitude exerts positive effect on willingness to pay, e.g., for organic food (Voon et al., 2011). We hypothesize the similar effect for microalgae-based food. Moreover, we believe that purchase intention will also have a positive effect on willingness to pay:

- Hypothesis 3: Purchase intention and positive attitude towards microalgae-based food will positively influence willingness to pay for this food.

In addition, as it is documented that microalgae-based food has high degree of healthiness and environmental sustainability, general health interest and environmental concern may positively influence consumers’ attitude towards this kind of food. Green consumer trends demonstrate that an influential group of aware and ethical consumers has emerged (e.g., Harrison et al., 2005; Hendarwan, 2002; Oke et al., 2020). Consumers are becoming increasingly aware of the consequences of their consumption choices, and thus more inclined to choose environmentally responsible products (e.g., Crane and Matten, 2004; Freestone and McGoldrick, 2008). Several studies provide support for this development. For example, Bjørner et al. (2004) show that an environmental label on a food product significantly affects consumer choices. It is especially true for consumers who care about the environment. Environmental concern is demonstrated to be a significant driver of sustainable behaviour and attitudes towards many sustainable products (Filimonau et al., 2020; Pagiaslis and Krontalis, 2014). Therefore, we hypothesize the following:

- Hypothesis 4: Environmental concern will positively influence consumers’ attitude towards microalgae-based food.

There is also a growing trend towards food healthiness. Many consumers are concerned about their health and prefer foods providing health benefits. For example, previous research indicates the high importance of health as a motivator for organic food consumption (e.g., Kriwy and Mecking, 2012). Moreover, studies (Weickert et al., 2021) show that consumers interested in a healthy diet are interested in microalgae. As microalgae-based food provides health benefits, we expect the following:

- Hypothesis 5: General health interest will positively influence consumers’ attitude towards microalgae-based food.

We also need to consider that microalgae-based food is still very novel as it does not have a significant history of consumption. Therefore, it is also necessary to consider the effect of consumers’ attitude towards innovation in food (Goldsmith et al., 1998; Perito et al., 2020).

- Hypothesis 6: Positive attitude towards innovation in food will positively influence consumers’ attitude towards microalgae-based food.

Moreover, as for any new food product, food neophobia – the reluctance to consume novel foods (Losada-Lopez et al., 2021) – can become a problem. The earlier research demonstrates that neophobia can prevent consumers from trying healthy alternative versions of already familiar products (Schickenberg et al., 2008). Thus, we hypothesize that food neophobia can have a negative effect on the attitude towards microalgae-based food.

- Hypothesis 7: Neophobia will negatively influence consumers’ attitude towards microalgae-based food.

Table 1
Descriptive statistics - Sample.

	Frequency	Percent
Respondent's gender		
Female	380	37.6%
Male	631	62.4%
Age group		
Young, 40 or less	502	49.7%
Older, 41 and up	509	50.3%
Geographical location - region		
Innlandet	54	5.3%
Møre og Romsdal	36	3.6%
Nordland	40	4.0%
Oslo	210	20.8%
Rogaland	84	8.3%
Troms og Finnmark	89	8.8%
Trøndelag	87	8.6%
Vestfold og Telemark	84	8.3%
Vestland	113	11.2%
Viken	214	21.2%
Level of education		
Lower secondary	47	4.6%
Upper secondary	296	29.3%
Higher education	659	65.2%
Other	9	0.9%
Urban or rural location		
City, 100 K +	389	38.5%
City, 20 K - 100K	282	27.9%
City, 500 - 20 K	178	17.6%
Rural	156	15.4%
Other	6	0.6%

3. Material and methods

3.1. Data collection and sample characteristics

To test the hypotheses discussed above, we conducted an online survey with a Norwegian consumer panel from a well-established data provider (380 females, 631 males; average age 42 years; stratified random sampling to address various income groups, education levels and geographical locations). To qualify, the respondents answered a screening question about their beer and bread consumption frequency (minimum one time per week for bread and one time per month for beer). Please see Table 1 for the sample details. The selected panel reflects the demographic situation in Norway, except the gender distribution and the education level. Norwegian population totals 5.4 million, with 49.5 per cent females and 50.5 per cent males (Statista, 2022a). Average age is 41 years (Statista, 2022b). Over 82 per cent of the population live in urban areas. As many as 44 per cent live in the Oslo Fjord region (Oslo, Viken and Vestfold og Telemark) (Statistics Norway, 2021). As for education levels in Norway, 36 per cent have higher education, 36.7 per cent have upper secondary education and 24.2 per cent have lower secondary education (Statistics Norway, 2022). The higher representation of males in the sample can be partly explained by a screening question about beer and bread consumption frequency and is acknowledged as one of the limitations. One of the explanations for the overrepresentation of respondents with higher education is the chosen data collection method (an online consumer panel); however, this method is considered being the predominant one for survey data collection worldwide.

The survey was organized in the following way. To begin with, the respondents got a short explanation of the concept of microalgae. Then respondents were asked to read the descriptions of two microalgae-based products (bread and beer) with special focus on physical attributes (e.g., taste, smell, appearance, and texture), positive health effects and environmental benefits. After that, respondents indicated their attitudes, purchase intentions and willingness to pay for each of microalgae-based products (bread and beer) on a five-point scale. Willingness to pay was measured by asking the following question: "If the taste is good, I would be willing to pay more for the microalgae-based bread/beer than for a

conventional one". Finally, respondents filled out several scales: attitude towards innovation in food; food neophobia; general health interest; environmental concern. Attitude towards innovation in food was measured with six items adapted from Goldsmith et al. (1998), e.g. "I buy new foods before anyone else I know", "Generally I am amongst the first of my circle of friends to buy new foods", "Compared to my friends, I purchase more new foods". Food neophobia was measured by six items adapted from Ritchey et al. (2003), e.g. "If I don't know what a food is, I won't try it", "At dinner parties, I will try new foods" (reversed item), "I am afraid to eat things I have never had before". General health interest was measured by six items adapted from Roininen et al. (1999), e.g. "I am very particular about the healthiness of food I eat", "I always follow a healthy and balanced diet", "It is important for me that my daily diet contains a lot of vitamins and minerals." Finally, environmental concern was measured with four items adapted from Dunlap et al. (2000), e.g. "Humans are severely abusing the environment", "If things continue on their present course, we will soon experience a major ecological catastrophe."

3.2. Statistical analysis

All statistical analyses were performed using Stata 17. Latent variables were identified using confirmatory factor analysis. The latent constructs are evaluated using Cronbach's alpha, item-based Cronbach's alpha and item-rest correlation coefficients. Note that items for the latent constructs were screened at two stages. First, latent constructs were evaluated using confirmatory factor analysis, where items loading onto the same latent construct were kept for further analysis. Then, at a second stage, one item was removed from the full SEM-model because it had a strong negative impact on the overall goodness of fit for both models (Bread and Beer).

For evaluating the fit of the measurement model, a range of measures was used.

First, we documented the factor loadings, the standard error of the factor loadings and their p-values. We also used Cronbach's alpha for evaluating the goodness of latent constructs in the measurement model. Convergent validity, or the degree of confidence we have that a trait is well measured by its items was measured using average variance extracted (AVE), that is, the level of variance captured by the construct vs the level of variance due to measurement error.¹ We also present the construct reliability measures (CR).²

Second, for evaluating discriminant validity – the degree to which measures of different traits are unrelated – we compared the value of AVE of an item to the largest square of the correlation of this item with all other items. This value of AVE for item *i* should be lower than the squared correlation if item *i* and item *j*.

The latent constructs meet the desired requirements for validity except for the Health interest latent construct (see Table 2). All latent constructs have AVE-values higher than 0.5, but the latent constructs Intention and Neophobia have scores lower than 0.7.

The only weak latent measure is the Health interest latent construct. Two of the items in this latent construct have factor loadings lower than 0.6 and the Cronbach's alpha is only 0.66 (optimally higher than 0.7), AVE is below 0.5 and CR below 0.7 (but above 0.5). However, we included this item in the analysis, both due to its contribution to the understanding of willingness to pay for novel foods, and because the overall scores of the models were significantly lower when excluding this latent construct.

Finally, all squared correlation between latent construct *i* and latent constructs $j \neq i$, $corr(i, j \neq i)$ are lower than the estimated average variance extracted for latent construct *i* (AVE_i), except for the latent

¹ Values of AVE above 0.7 are considered very good, whereas the level of 0.5 is acceptable.

² Values of CR above 0.7 is considered acceptable.

Table 2
Items and latent variables.

	Loading	st.err.	p-value	alpha	AVE	CR
Intention1	0.878	79.059	0.000	0.87	0.69	0.869
Intention2	0.855	71.246	0.000			
Intention3	0.743	45.788	0.000			
Attitude4	0.824	54.193	0.000	0.84	0.642	0.843
Attitude5	0.755	44.208	0.000			
Attitude8	0.780	47.899	0.000			
Envir. concern4	0.813	41.471	0.000	0.79	0.582	0.803
Envir. concern3	0.858	44.723	0.000			
Envir. concern2	0.592	24.861	0.000			
Health interest1	0.579	17.863	0.000	0.66	0.412	0.671
Health interest3	0.787	22.287	0.000			
Health interest6	0.532	16.674	0.000			
Attitude t/Innov.2	-0.925	-113.343	0.000	0.92	0.785	0.916
Attitude t/Innov.3	-0.882	-92.348	0.000			
Attitude t/Innov.1	-0.850	-79.142	0.000			
Subjective norms8	0.761	37.434	0.000	0.73	0.560	0.718
Subjective norms7	0.770	38.065	0.000			
Neophobia3	0.855	50.987	0.000	0.83	0.619	0.829
Neophobia4	0.746	39.603	0.000			
Neophobia6	0.755	40.572	0.000			

Note: Loading is the factor loading for the items in the SEM, st.err. is standard error.

Table 3
Statistics for evaluating model goodness of fit.

Model	CFI	TLI	RMSEA	SRMR
Bread: Model 1	0.844	0.864	0.085	0.178
Bread: Model 2	0.884	0.900	0.075	0.154
Bread: Model 3	0.948	0.956	0.050	0.086
Beer: Model 1	0.859	0.876	0.081	0.173
Beer: Model 2	0.809	0.834	0.097	0.164
Beer: Model 3	0.955	0.962	0.047	0.080

construct Subjective norms, the maximum squared correlation with another latent construct is 0.640 (the latent construct Intention), and the AVE for Subjective norms is 0.56.

The proposed models' goodness of fit was estimated using Structural Equation Modelling (SEM). Both models (bread and beer) and variants of these, are evaluated using two absolute fit measures: root mean squared error of approximation (RMSEA) and standardized root mean square residual (SRMR), and two measures of relative fit measures: the comparative fit index (CFI) and the Tucker-Lewis index (TLI). Values of RMSEA below 0.05 is considered good fit, while values between 0.05 and 0.08 is considered acceptable fit. Values higher than 0.1 is considered poor fit. A value of less than 0.08 for SRMR is considered good fit. Values of CFI higher than 0.95 is considered good fit, while values between 0.95 and 0.9 is considered ok fit. It is desirable that the TLI is higher than 0.95. For an overview of this, see e.g. Hair et al. (2006).

The proposed general model produces results that are slightly lower than desired, see Model 1 in Table 3.

However, two modifications were made. First, we added covariance relations between i) the latent constructs Environmental concern and Neophobia, and ii) the latent constructs Attitude towards innovation and Neophobia. This is referred to as Model 2 in Table 2. From the dataset, it looks as if a subset of the participants has very strong opinions about aspects related to climate change (Environmental concern) and aspects related to ethnic food/food from other cultures (Neophobia). Some respondents fully agree on these items, while other respondents fully disagree. Hence, the items reflect these "socio-political" opinions. The items underlying the latent constructs Attitude towards innovation and Neophobia both relate to trying novel or unknown foods, and therefore, a covariance term between these latent constructs increases fit. Second, we removed one of the items in the Subjective norms construct. This item had a significant negative effect on statistical fit. The final model

Table 4
Bread, Model 3: Direct, indirect and total effects.

Relation	Direct effect	Indirect effect	Total effect
Measurement Model			
Willingness to Pay			
** Intention	0.868***	n.a.***	0.868***
** Attitude	-0.227***	0.254**	0.026***
** Environmental concern	n.a.***	0.006***	0.006***
** Health interest	n.a.***	-0.004***	-0.004***
** Attitude towards innovation	0.127***	0.001***	0.128***
** Subjective norms	n.a.***	0.573***	0.573***
** Neophobia	n.a.***	0.003***	0.003***
Structural Model			
Intention			
** Attitude	0.292***	n.a.***	0.292***
** Environmental concern	n.a.***	0.071**	0.071**
** Health interest	n.a.***	-0.045***	-0.045***
** Attitude towards innovation	n.a.***	0.011***	0.011***
** Subjective norms	0.649***	0.106***	0.755***
** Neophobia	n.a.***	0.031***	0.031***
Attitude			
** Environmental concern	0.243***	n.a.***	0.243***
** Health interest	-0.154***	n.a.***	-0.154***
** Attitude towards innovation	0.038***	n.a.***	0.038***
** Subjective norms	0.362***	n.a.***	0.362***
** Neophobia	0.107***	n.a.***	0.107***

* $p < 0.05$,
 ** $p < 0.01$,
 *** $p < 0.001$.

is referred to as Model 3, and from Table 2 we see that this model, for both products (beer and bread), has desirable statistical fit.

4. Results

Please see results in Tables 3 (bread) and 4 (beer) and Figs. 1 (bread) and 2 (beer).

First, in the structural model, Environmental concern, Health interest and Subjective norms all significantly affect the latent construct Attitude. However, Attitude towards innovation does not affect Attitude, and Neophobia only have a weak impact on Attitude. Similar results are found for impact on Purchase intentions, both for bread and beer. Attitude also impacts Purchase intentions. It should be noted that the significant impacts from Environmental concern and Health interest on Purchase intentions is via Attitude, while the impact from Subjective norms on Purchase intentions is both direct (strong) and indirect via Attitude (weaker).

In the measurement model, the latent variables Purchase Intention, Attitude towards innovation and Subjective norms impact the Willingness to pay positively (highly significant). The indirect impact Attitude towards innovation has on Willingness to pay is small and non-significant, while the direct impact is large and highly significant. This contrasts the impact Attitude has on Willingness to pay. First, both the direct and indirect effects are highly significant and of the same magnitude. Second, the indirect and direct effects are of opposite sign, and the total effect is not significantly different from zero. In total, Attitude does not affect Willingness to pay significantly (zero), while Attitude affects Willingness to pay positively via Purchase intentions and the direct effect is negative. This is commonly referred to as inconsistent mediation (MacKinnon et al., 2007).

In addition, the results are stable across groups of consumers. We do not find any substantial differences when we differentiate between age groups or gender, see tables in Appendix A. Table 5

Table 6 provides an overview of the hypotheses that were supported or not supported.

As we can see, Hypotheses 1 and 2 are supported. As expected, based on the theory of reasoned action (Ajzen and Fishbein, 1980), we find that

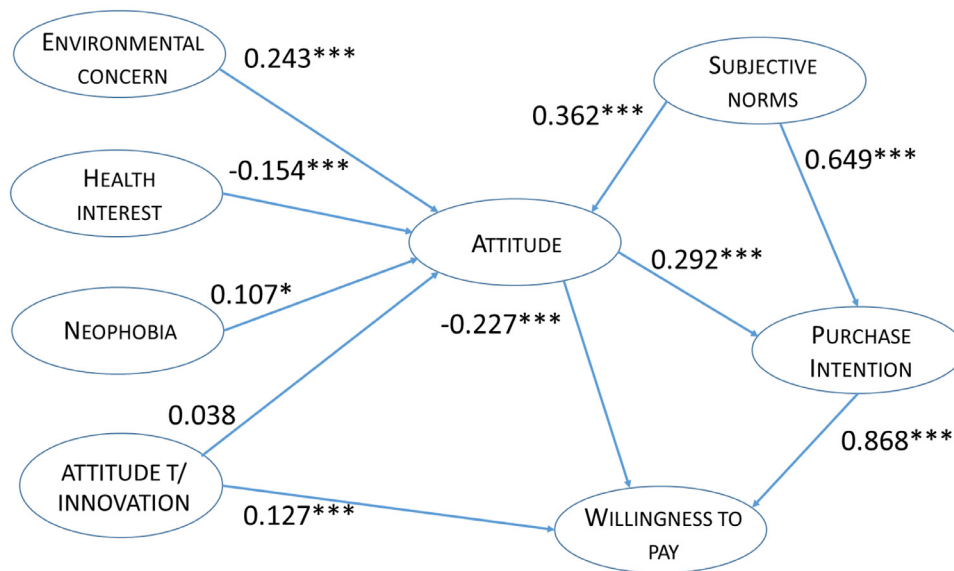


Fig. 1. Structural equation model for bread
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

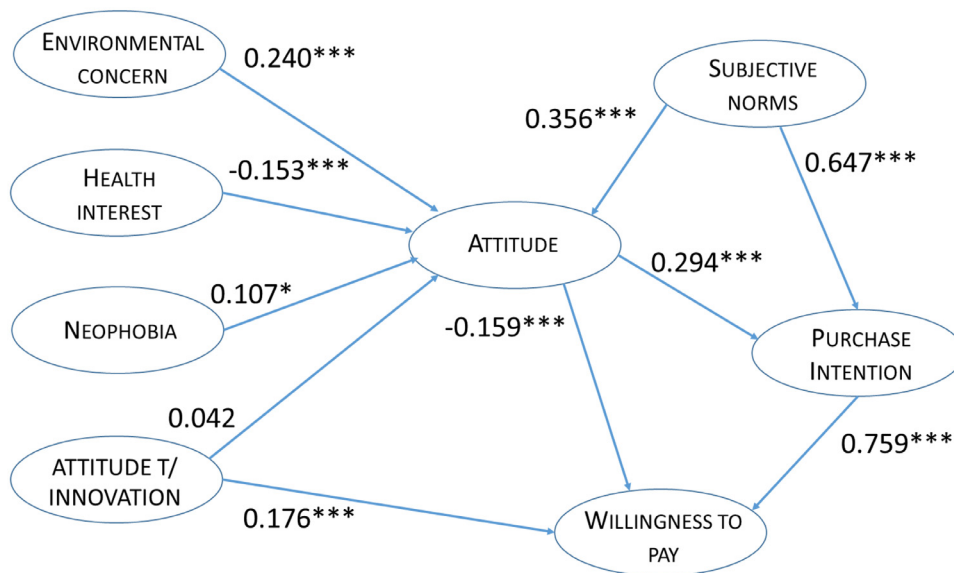


Fig. 2. Structural equation model for beer
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

positive attitude and favourable subjective norms towards microalgae-based products positively influence purchase intentions. Moreover, our study demonstrates that subjective norms have an indirect positive effect on willingness to pay for microalgae-based food and direct positive effect on the attitude towards microalgae-based products. Hypothesis 3 is partially supported for bread and fully supported for beer. For beer, purchase intention and positive attitude towards microalgae-based products will positively influence willingness to pay for this food. For bread, we do not find a significant effect for positive attitude. Hypothesis 4 is supported for both products as environmental concern positively influences consumers' attitude towards microalgae-based food. It also indirectly influences the purchase intentions. Hypothesis 5 is not supported, and we find a significant opposite effect, i.e., general health interest negatively influences consumers' attitude towards microalgae-based food and indirectly negatively influences purchase intentions. Hypothesis 6 is also not supported; attitude towards innovation in food does not have any significant influence on consumers' attitude towards microalgae-based

food. However, we find that it has a direct positive effect on willingness to pay for microalgae-based food. As for Hypothesis 7, we find a surprising significant opposite effect. Neophobia positively influences consumers' attitude towards microalgae-based food. In addition, it has a significant indirect positive effect on purchase intentions.

5. Discussion

Overall, the results indicate that environmental concern and subjective norms (i.e., social norms on microalgae-based food) have significant positive effect on consumers' attitude and purchase intentions towards microalgae-based food. Purchase intentions, attitude towards innovation in food and subjective norms positively and highly significantly impact the willingness to pay for microalgae-based food. To conclude, microalgae-based food especially appeals to the environmentally engaged and innovative consumers, which is in line with the previous research on sustainable and new food (Pagiaslis and Krontalis, 2014;

Table 5
Beer, Model 3: Direct, indirect and total effects.

Relation	Direct effect	Indirect effect	Total effect
Measurement Model			
Willingness to Pay			
** Intention	0.759***	n.a.***	0.759***
** Attitude	-0.159***	0.223***	0.064***
** Environmental concern	n.a.***	0.015***	0.015***
** Health interest	n.a.***	-0.010***	-0.010***
** Attitude towards innovation	0.176***	0.003***	0.179***
** Subjective norms	n.a.***	0.514***	0.514***
** Neophobia	n.a.***	0.007***	0.007***
Structural Model			
Intention			
** Attitude	0.294***	n.a.***	0.294***
** Environmental concern	n.a.***	0.071***	0.071***
** Health interest	n.a.***	-0.045***	-0.045***
** Attitude towards innovation	n.a.***	0.012***	0.012***
** Subjective norms	0.647***	0.105***	0.752***
** Neophobia	n.a.***	0.031***	0.031***
Attitude			
** Environmental concern	0.240***	n.a.***	0.240***
** Health interest	-0.153***	n.a.***	-0.153***
** Attitude towards innovation	0.042***	n.a.***	0.042***
** Subjective norms	0.356***	n.a.***	0.356***
** Neophobia	0.107***	n.a.***	0.107***

* $p < 0.05$,
 ** $p < 0.01$,
 *** $p < 0.001$.

Table 6
Overview of the hypotheses.

<i>Hypothesis 1:</i> Positive attitude towards microalgae-based food will positively influence purchase intentions for this food.	Supported
<i>Hypothesis 2:</i> Favourable subjective norms towards microalgae-based food will positively influence purchase intentions for this food.	Supported
<i>Hypothesis 3:</i> Purchase intention and positive attitude towards microalgae-based food will positively influence willingness to pay for this food.	Partially supported for bread (purchase intention) Supported for beer
<i>Hypothesis 4:</i> Environmental concern will positively influence consumers' attitude towards microalgae-based food.	Supported
<i>Hypothesis 5:</i> General health interest will positively influence consumers' attitude towards microalgae-based food.	Not supported (significant opposite effect)
<i>Hypothesis 6:</i> Positive attitude towards innovation in food will positively influence consumers' attitude towards microalgae-based food.	Not supported
<i>Hypothesis 7:</i> Neophobia will negatively influence consumers' attitude towards microalgae-based food.	Not supported (significant opposite effect)

Perito et al., 2020). The marketing efforts should therefore focus on this particular consumer segment as they can act as innovators and early adopters for microalgae-based food.

The current study also emphasizes a central role of the opinions of others (subjective norms) for microalgae-based food. The positive effect of subjective norms on purchase intentions was expected based on the theory of reasoned action (Ajzen and Fishbein, 1980); nevertheless, their effect was extended also to consumers' attitudes and willingness to pay for this food. Previous research on organic food (Tarkiainen and Sundqvist, 2005) demonstrates that subjective norms may affect buying intention indirectly through attitude formation. In our study, we however find both direct and indirect effect on purchase intentions. This further supports the idea proposed by Al-Swidi et al. (2014) that subjective norms have a more superior role in consumer behaviour than generally expected. It is especially true for sustainable consumption as it is influenced by social norms to a large degree (Kollmuss and Agyeman, 2002).

This finding indicates that marketers have to target the opinion leaders and reference groups to increase the demand for microalgae-based food.

What we find as surprising is that general health interest has a significant negative direct effect on consumers' attitude towards microalgae-based food and indirectly negatively influences purchase intentions. This is opposite to what we expected based on the previous literature (Kriwy and Mecking, 2012). One of the possible explanations is that consumers' knowledge on microalgae and their potential application in food is still very limited (Lafarga et al., 2021), and consumers are therefore still sceptical towards its health benefits. Lack of information can reduce the acceptance of novel food. It is thus crucial to raise consumer knowledge about microalgae to increase their potential to be used as a food ingredient.

Another surprising finding is that neophobia positively influences consumers' attitude towards microalgae-based food and indirectly positively influences purchase intentions. By its definition, neophobia should have a negative effect on consumer behaviour towards such novel food as microalgae. It is difficult to explain this finding and further research is necessary to understand its implications.

6. Conclusion

The current study examines how various factors influence consumers' attitude, purchase intention and willingness to pay for microalgae-based bread and beer. An online survey with a consumer panel ($N = 1011$) was conducted, and a structural equation modelling procedure was implemented. The following effects are identified. Environmental concern and subjective norms have significant positive effect on consumers' attitude and purchase intentions towards microalgae-based food. Purchase intentions, attitude towards innovation in food and subjective norms positively and significantly impact the willingness to pay for microalgae-based food.

This study has its limitations, which future research may address. First, it could be extended to other national contexts and product categories. Culture can play an important role for consumption of sustainable food (Diaconeasa et al., 2021) and therefore future research should address other countries than Norway. Moreover, it is necessary to study other food products to generalize the findings. Finally, in the current consumer panel, we have an overweight of males, partly due to a screening question about beer and bread consumption frequency (minimum one time per week for bread and one time per month for beer). However, we do not find any substantial differences when we differentiate between gender (see Appendix A). Still, future studies can seek to achieve a more equal sample distribution.

Despite its limitations, the current study contributes to the literature on consumer behaviour towards novel food, in particular the emerging stream of literature on microalgae-based food. Microalgae-based food represents a new trend in sustainable consumption as it has both health benefits and low-carbon profile. However, this food experiences challenges in consumer acceptance due to its peculiarities (especially sensory characteristics) and low consumer knowledge. Understanding consumer perceptions of such food and which factors influence the purchase behaviour for microalgae-based food products is therefore important. This study helps practitioners in their efforts to evaluate consumer interest for microalgae-based food and develop effective marketing strategies for its further promotion. As mentioned above, we advise marketers to focus on the environmentally engaged consumers and target the opinion leaders and reference groups. Additionally, greater efforts in increasing consumer knowledge on microalgae as a food ingredient are recommended. The findings have also broad societal implications as getting acceptance for new sources of sustainable protein supply is highly crucial for development of a sustainable food system.

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Declaration of Competing Interests

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 was explained to consumers in the online questionnaire. They were informed that all data will be de-identified and only reported in the aggregate. All participants acknowledged an informed consent statement in order to participate in the study. They were able to withdraw from the survey at any time without giving a reason.

Microalgae-Based Food: Purchase Intentions and Willingness to Pay

Natalia Maehle and Frode Skjeret.

Appendix A

Analyses of differences between groups of respondents (age and gender)

Table A.1

Beer, Model 3. Younger respondents (40 or less): Direct, indirect and total effects from Structural Equation Model.

Relation Measurement Model	Direct effect	Indirect effect	Total effect
Willingness to Pay			
** Intention	0.778	n.a.	0.778
** Attitude	-0.155	0.096	-0.059
** Environmental concern	n.a.	-0.022	-0.022
** Health interest	n.a.	0.011	0.011
** Attitude towards innovation	0.166	0.003	0.169
** Subjective norms	n.a.	0.583	0.583
** Neophobia	n.a.	-0.004	-0.004
Structural Model			
Intention			
** Attitude	0.123	n.a.	0.123
** Environmental concern	n.a.	0.045	0.045
** Health interest	n.a.	-0.023	-0.023
** Attitude towards innovation	n.a.	-0.006	-0.006
** Subjective norms	0.777	0.045	0.822
** Neophobia	n.a.	0.009	0.009
Attitude			
** Environmental concern	0.363	n.a.	0.363
** Health interest	-0.188	n.a.	-0.188
** Attitude towards innovation	-0.051	n.a.	-0.051
** Subjective norms	0.365	n.a.	0.365
** Neophobia	0.076	n.a.	0.076

Table A.2

Beer, Model 3. Older respondents (over 40): Direct, indirect and total effects from Structural Equation Model.

Relation Measurement Model	Direct effect	Indirect effect	Total effect
Willingness to Pay			
** Intention	0.660	n.a.	0.660
** Attitude	-0.131	0.184	0.053
** Environmental concern	n.a.	0.014	0.014
** Health interest	n.a.	-0.008	-0.008
** Attitude towards innovation	0.198	0.003	0.201
** Subjective norms	n.a.	0.453	0.453
** Neophobia	n.a.	0.003	0.003
Structural Model			
Intention			
** Attitude	0.279	n.a.	0.279
** Environmental concern	n.a.	0.073	0.073
** Health interest	n.a.	-0.040	-0.040
** Attitude towards innovation	n.a.	0.016	0.016
** Subjective norms	0.661	0.088	0.749
** Neophobia	n.a.	0.014	0.014
Attitude			
** Environmental concern	0.261	n.a.	0.261
** Health interest	-0.143	n.a.	-0.143
** Attitude towards innovation	0.058	n.a.	0.058
** Subjective norms	0.315	n.a.	0.315
** Neophobia	0.052	n.a.	0.052

Table A.3

Beer, Model 3. Female respondents: Direct, indirect and total effects from Structural Equation Model.

Relation Measurement Model	Direct effect	Indirect effect	Total effect
Willingness to Pay			
** Intention	0.783	n.a.	0.783
** Attitude	-0.125	0.170	0.045
** Environmental concern	n.a.	0.008	0.008
** Health interest	n.a.	-0.006	-0.006
** Attitude towards innovation	0.206	-0.001	0.205
** Subjective norms	n.a.	0.568	0.568
** Neophobia	n.a.	0.008	0.008
Structural Model			
Intention			
** Attitude	0.217	n.a.	0.217
** Environmental concern	n.a.	0.041	0.041
** Health interest	n.a.	-0.027	-0.027
** Attitude towards innovation	n.a.	-0.004	-0.004
** Subjective norms	0.698	0.103	0.801
** Neophobia	n.a.	0.037	0.037
Attitude			
** Environmental concern	0.187	n.a.	0.187
** Health interest	-0.124	n.a.	-0.124
** Attitude towards innovation	-0.019	n.a.	-0.019
** Subjective norms	0.476	n.a.	0.476
** Neophobia	0.172	n.a.	0.172

Table A.4

Beer, Model 3. Male respondents: Direct, indirect and total effects from Structural Equation Model.

Relation	Direct effect	Indirect effect	Total effect
Measurement Model			
Willingness to Pay			
** Intention	0.660	n.a.	0.660
** Attitude	-0.131	0.184	0.053
** Environmental concern	n.a.	0.014	0.014
** Health interest	n.a.	-0.008	-0.008
** Attitude towards innovation	0.198	0.003	0.201
** Subjective norms	n.a.	0.453	0.453
** Neophobia	n.a.	0.003	0.003
Structural Model			
Intention			
** Attitude	0.279	n.a.	0.279
** Environmental concern	n.a.	0.073	0.073
** Health interest	n.a.	-0.040	-0.040
** Attitude towards innovation	n.a.	0.016	0.016
** Subjective norms	0.661	0.088	0.749
** Neophobia	n.a.	0.014	0.014
Attitude			
** Environmental concern	0.261	n.a.	0.261
** Health interest	-0.143	n.a.	-0.143
** Attitude towards innovation	0.058	n.a.	0.058
** Subjective norms	0.315	n.a.	0.315
** Neophobia	0.052	n.a.	0.052

Table A.5

Bread, Model 3. Younger respondents (40 or less): Direct, indirect and total effects from Structural Equation Model.

Relation	Direct effect	Indirect effect	Total effect
Measurement Model			
Willingness to Pay			
** Intention	0.943	n.a.	0.943
** Attitude	-0.367	0.264	-0.102
** Environmental concern	n.a.	-0.039	-0.039
** Health interest	n.a.	0.019	0.019
** Attitude towards innovation	0.067	0.003	0.071
** Subjective norms	n.a.	0.649	0.649
** Neophobia	n.a.	-0.007	-0.007
Structural Model			
Intention			
** Attitude	0.280	n.a.	0.280
** Environmental concern	n.a.	0.106	0.106
** Health interest	n.a.	-0.053	-0.053
** Attitude towards innovation	n.a.	-0.010	-0.010
** Subjective norms	0.724	0.094	0.819
** Neophobia	n.a.	0.020	0.020
Attitude			
** Environmental concern	0.379	n.a.	0.379
** Health interest	-0.189	n.a.	-0.189
** Attitude towards innovation	-0.034	n.a.	-0.034
** Subjective norms	0.337	n.a.	0.337
** Neophobia	0.070	n.a.	0.070

Table A.6

Bread, Model 3. Older respondents (over 40): Direct, indirect and total effects from Structural Equation Model.

Relation	Direct effect	Indirect effect	Total effect
Measurement Model			
Willingness to Pay			
** Intention	0.631	n.a.	0.631
** Attitude	0.003	0.185	0.188
** Environmental concern	n.a.	0.029	0.029
** Health interest	n.a.	-0.021	-0.021
** Attitude towards innovation	0.123	0.018	0.141
** Subjective norms	n.a.	0.468	0.468
** Neophobia	n.a.	0.020	0.020
Structural Model			
Intention			
** Attitude	0.293	n.a.	0.293
** Environmental concern	n.a.	0.045	0.045
** Health interest	n.a.	-0.032	-0.032
** Attitude towards innovation	n.a.	0.027	0.027
** Subjective norms	0.635	0.105	0.740
** Neophobia	n.a.	0.031	0.031
Attitude			
** Environmental concern	0.154	n.a.	0.154
** Health interest	-0.110	n.a.	-0.110
** Attitude towards innovation	0.093	n.a.	0.093
** Subjective norms	0.357	n.a.	0.357
** Neophobia	0.106	n.a.	0.106

Table A.7

Bread, Model 3. Female respondents: Direct, indirect and total effects from Structural Equation Model.

Relation	Direct effect	Indirect effect	Total effect
Measurement Model			
Willingness to Pay			
** Intention	0.960	n.a.	0.960
** Attitude	-0.180	0.236	0.056
** Environmental concern	n.a.	0.011	0.011
** Health interest	n.a.	-0.007	-0.007
** Attitude towards innovation	0.073	-0.001	0.072
** Subjective norms	n.a.	0.675	0.675
** Neophobia	n.a.	0.009	0.009
Structural Model			
Intention			
** Attitude	0.246	n.a.	0.246
** Environmental concern	n.a.	0.047	0.047
** Health interest	n.a.	-0.031	-0.031
** Attitude towards innovation	n.a.	-0.003	-0.003
** Subjective norms	0.676	0.115	0.792
** Neophobia	n.a.	0.041	0.041
Attitude			
** Environmental concern	0.190	n.a.	0.190
** Health interest	-0.124	n.a.	-0.124
** Attitude towards innovation	-0.014	n.a.	-0.014
** Subjective norms	0.470	n.a.	0.470
** Neophobia	0.168	n.a.	0.168

Table A.8

Bread, Model 3. Male respondents: Direct, indirect and total effects from Structural Equation Model.

Relation	Direct effect	Indirect effect	Total effect
Measurement Model			
Willingness to Pay			
** Intention	0.800	n.a.	0.800
** Attitude	-0.266	0.254	-0.012
** Environmental concern	n.a.	-0.003	-0.003
** Health interest	n.a.	0.002	0.002
** Attitude towards innovation	0.168	-0.001	0.167
** Subjective norms	n.a.	0.503	0.503
** Neophobia	n.a.	-0.001	-0.001
Structural Model			
Intention			
** Attitude	0.318	n.a.	0.318
** Environmental concern	n.a.	0.087	0.087
** Health interest	n.a.	-0.047	-0.047
** Attitude towards innovation	n.a.	0.021	0.021
** Subjective norms	0.633	0.095	0.728
** Neophobia	n.a.	0.017	0.017
Attitude			
** Environmental concern	0.274	n.a.	0.274
** Health interest	-0.148	n.a.	-0.148
** Attitude towards innovation	0.066	n.a.	0.066
** Subjective norms	0.299	n.a.	0.299
** Neophobia	0.053	n.a.	0.053

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