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Microalgae-based Food: Consumer Perception and Willingness to Pay in Austria—a Discrete Choice Based Experiment

Oliver Meixner, Richard Nieschalk, and Rainer Haas

Institute of Marketing and Innovation, Department of Economics and Social Sciences, University of Natural Resources and Life Sciences, Vienna, 1180 Vienna, Austria.
oliver.meixner@boku.ac.at; rainer.haas@boku.ac.at.

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ABSTRACT

Algae-based foods have been gaining increasing popularity in recent years and hold tremendous potential, provided that there is greater awareness and knowledge about microalgae-based foods within both the general population and the food industry. These products not only offer health benefits for the human body but are also cost-effective and environmentally sustainable to produce. Using a discrete choice experiment (DCE), we assessed consumer perception and willingness to pay (WTP) of Austrian consumers for innovative food items made from microalgae, using algae crackers as an illustrative example. To approximate the weighting of the product attributes of origin, price, flavor, production method and packaging, we employed Choice Based Conjoint Analysis (CBCA) through an online survey (n = 301 participants). Subsequently, we approximated WTP for each product attribute based on the outcomes of the CBCA. The study reveals that, on the whole, microalgae-based food products are favorably perceived by consumers. The findings generally align with prior research in the literature, albeit with some noteworthy distinctions. For instance, there is a higher WTP for organic microalgae-based food compared to similar studies where regional production was evaluated to be of higher importance. Consequently, innovative microalgae foods seem to have significant potential in consumer food markets. Food producers should consider the expectations and perceptions of consumers in order to be able to successfully introduce novel microalgae food products in this, currently, niche market.

***Keywords**: Algae foods; consumer behavior; Choice Based Conjoint Analysis; novel food; willingness to pay; niche market.*

1 Introduction

Plant-based proteins are the main source of protein for food, but in general, meat consumption is increasing on a global level. Microalgae-based proteins could be a reliable source to meet the population's need for protein and could become a "game changer" in the global trend towards increased animal-based nutrition. As Chen et al. (2022, p. 99) report, "Microalgae are the most promising source for new food products". Microalgae-based proteins have some important advantages compared to established (plant-based and animal-based) protein sources such as lower land requirements, usage of non-arable land for cultivation, less freshwater usage, and the potential to be produced in seawater (Caporgno and Mathys, 2018). Algae, especially microalgae, offer a sustainable, alternative protein source and it is estimated that they will account for 18% of protein sources on the market by the year 2050. There are between 200,000 and 800,000 microalgae species with only a few utilized for food production. The idea of using microalgae as a source of bulk proteins is relatively new. However, in comparison to other protein sources, microalgae sourced proteins can offer several advantages, such as meeting the population's need for protein while having a lower land requirement compared to animal-based protein production. Microalgae have even lower land requirements than other plant-based proteins (Caporgno and Mathys, 2018). Microalgae also have some significant health benefits, containing various bio-active substances which act as an anticarcinogenic, antioxidative, antihypertensive as well as hepatoprotective resource (Koyande et al., 2019). They also contain high amounts of beneficial omega-3 fatty acids (Weinrich and Elshiewy, 2019).

2 Literature Review

There is already a market for products with health-promoting properties, triggered by new insights into the relationship between nutrition and health (Tuorila and Hartmann, 2020). In the mid-2010s, dried whole algae as well as various high-value molecules and colorants were the most available food and feed products derived from microalgae available on the market (Vigani et al., 2015). Even though there has been an exponential growth in the niche market of microalgae-derived products in the last decades, functional foods based on microalgae remain niche products due to the high production costs of harvesting and component extraction (Koyande et al., 2019). Major obstacles to the successful market introduction of microalgae-based foods are low public awareness of their health benefits and the lack of incentives for production. These obstacles need to be addressed (e.g., by information campaigns) to increase public awareness and to realize new applications in the food and nutraceutical industry for microalgae products to become mainstream. Furthermore, microalgae have great potential to solve major future issues related to climate change and to meet the nutritional requirements of a growing global population (Koyande et al., 2019). Microalgae-based food and feed products are relatively small in their total market size and production volumes compared to foods derived from cereals or other commodity crops. Nevertheless, there has been a five-fold increase in microalgae production in food and feed since the early 2000s (Vigani et al., 2015). Caporgno and Mathys (2018) found that the sector for microalgae products, either as final product or biomass, is expanding with start-ups and big enterprises indicating their interest on a global scale. In particular, in the food supplement market, whole microalgae cells have a huge potential. Products based on microalgae together with bio functional compounds could generate higher selling prices than common food supplements and thereby improve the economic operability to cover the higher costs due to new cultivation and processing technologies.

The market introduction of new food products also involves other significant barriers, for instance the need to obtain approval from the regulatory authorities (Caporgno and Mathys, 2018). According to European law, foods can be introduced to the European market without any prior permission except for novel food products and novel food ingredients. Before they can be distributed in the EU food market, novel foods must be tested in a uniform safety assessment to ensure that they are safe for consumers and should not be misleading in their description (Österreichische Agentur für Gesundheit und Ernährungssicherheit, 2020). If a novel product and an already established product are not comparable, the attributes of the new product are considered unknown. Likewise, a product that is known in another culture but is still unknown in the current culture can also be considered novel (Tuorila and Hartmann, 2020). By definition, novel foods are foods and food ingredients which fall into one of four categories (Österreichische Agentur für Gesundheit und Ernährungssicherheit, 2020): (1) Foods with a new or modified primary molecular structure; (2) foods that consist of or are isolated from microorganisms, fungi or algae products (such as algae oil); (3) foods which contain exotic and unknown plants or parts of plants in Europe (such as food ingredients isolated from animals); (4) foods that are produced with a new or unusual process, which changes the composition or structure (e.g. fruit preparations produced using a high-pressure pasteurization process).

Another issue for the successful introduction of microalgae-based food might be food neophobia, which is seen as the general skepticism of consumers towards novel foods (Henriques et al., 2009). To overcome food neophobia, researchers have found that the most important factor in creating familiarity is direct exposure to a food; theoretical knowledge about a product is only of secondary importance (Tuorila and Hartmann, 2020). Furthermore, Tuorila and

Hartmann (2020) found out that men are a little more neophobic than women and older people are more prone to neophobic behavior than younger people. Indicators of consumer demand for a certain product could be price premiums, where the consumer pays a higher price which is justified by the value of the product to the individual (Krystallis and Chryssohoidis, 2005). Value can be defined as the evaluation of an experience of a product or service, based on all the benefits and disadvantages associated with it (Le Gall-Ely, 2009; Wertenbroch and Skiera, 2002).

This is reflected in willingness to pay (WTP) for novel food. Confirming McFarlane and Pliner (1997), the relative willingness to try novel food increased linearly with age. This might be shown on the example of organic food with additional ethical characteristics such as animal welfare, biodiversity or fair prices for producers. Zander and Hamm (2010) conducted a study with participants from Austria, Switzerland and Germany, in which 6% of consumers chose a low-priced organic product without additional value and an overall WTP of at least 20% for added ethical properties of organic food. This example clearly shows that alternative, more sustainable food products might result in higher WTP and market share, if consumers understand and appreciate the food products. To improve our knowledge of microalgae food products, this study intended to answer the following research questions:

1. *How important are selected product attributes of microalgae food products for consumers (including the utility of attribute levels)?*
2. *To what extent are consumers willing to pay a price premium for selected characteristics of a microalgae food product?*

3 Material and Methods

In order to assess the importance of microalgae food product characteristics, a conjoint analysis approach is applied, along with an evaluation of the WTP. A Choice Based Conjoint Analysis (CBCA) is generally applied in the marketing sector in the areas of pricing, product development and aspects of market segmentation. The method can be used for comprehensive practical applications such as optimal product or service design, price determination or preference determination (Baier and Brusch, 2009). Among other methods, the CBCA is commonly used for surveys in current consumer food studies (Anabtawi et al., 2020; Meixner and Katt, 2020; Weinrich and Elshiewy, 2019). Studies using CBCA examine the preference and WTP for meat substitutes based on microalgae (Weinrich and Elshiewy, 2019). Other studies deal with the health and safety of food, such as those by Anabtawi et al. (2020) who researched the perceived healthiness of food items and the traffic light front of pack nutrition labelling, or those assessing the impact of COVID-19 on consumer food safety perceptions (Meixner and Katt, 2020). Further publications used CBCA to observe the development of new products (van Kleef et al., 2005), the acceptance of functional foods (Annunziata and Vecchio, 2013), or novel bread, milk and meat food items (Cox et al., 2011). Additionally, CBCA is often used in combination with other quantitative and qualitative research methods such as cross-sectional surveys, multi-item scales, laddering interviews and cluster analysis (Anabtawi et al., 2020; Annunziata and Vecchio, 2013; van Kleef et al., 2005; Weinrich and Elshiewy, 2019).

Concerning WTP, Krystallis and Chryssohoidis (2005) revealed that the WTP measured by a conjoint analysis is considered more realistic than methods where consumers are interviewed directly. Also Meixner and Katt (2020) and Weinrich and Elshiewy (2019) primarily used this methodology in their research to determine consumers' WTP. Hofstetter et al. (2020) and Miller et al. (2011) discuss how WTP can be measured most effectively and which methodological approach is best suited for which context. Hofstetter et al. (2020) argue that both methods, dichotomous-choice as an indirect single question approach and CBCA as an indirect multiple question approach, can be applied to individual features of a product.

Methodologically, consumers make hypothetical, repeated product choices which are coded as binary data (choice/no-choice). Based on these binary coded choice decisions the importance of product attributes and attribute levels (product characteristics) are approximated based on the random utility theory (McFadden, 1974). The choice decision of consumer j can be expressed as $U_{ijs} = V_{ijs} + \varepsilon_{ijs}$, with the deterministic element $V_{ijs} = \beta_j \cdot X_{ijs}$. The stochastic element ε_{ijs}. X_{ijs} is the vector of attributes with the i^{th} option of choice set *s*; β_j is the (unknown) vector describing the preferences of the j^{th} individual. In accordance with Meixner and Katt (2020), β_j is approximated confirming formula (1) to assess individual part-worth utilities of attributes by means of Hierarchical Bayes estimation.

$$U_{ijs} = \beta_0 + \beta_1 \cdot \text{origin}_{ijs} + \beta_2 \cdot \text{price}_{ijs} + \beta_3 \cdot \text{flavor}_{ijs} + \beta_4 \cdot \text{prod.method}_{ijs} + \beta_5 \cdot \text{packaging}_{ijs} + \varepsilon_{ijs} \quad (1)$$

WTP can then be interpreted as the ratio $-\beta_1/\beta_{price}$ (Louviere and Islam, 2008) where β_1 represents the utility per level and β_{price} the negative linear price function (higher prices are less preferable). In other words, deviations in the utility of product features can be compensated for by changing the price level accordingly (and thus increasing/decreasing the

utility of the price level confirming the linear price function). The approximations were done applying a Hierarchical Bayes approach comparable to the usual CBCA studies (Meixner and Katt, 2020). "[R]ecent advances in Bayesian estimation make the estimation of these models computationally feasible, offering advantages in model interpretation over models based on indirect utility, and descriptive models that tend to be highly parameterized" (Chandukala et al., 2008). Via this approach, it is possible to approximate individual part-worth utilities.

The CBCA usually consist of the following steps: (i) establishing attributes; (ii) assigning attribute levels; (iii) designing the choice sets; (iv) generating and pre-testing the questionnaire; (v) Analyzing the data (Mangham et al., 2009).

Due to the good comparability and similarity to products already established on the Austrian market, the research product chosen within this study are *algae crackers*. These are dried and pressed microalgae that can be refined with spelt flour, linseed, pumpkin seeds, amaranth and other natural ingredients. The research design of this work is based on the specifications of Weinrich and Elshiewy (2019). Steps (i) and (ii): The attributes and attribute levels of these algae crackers consist of (1) origin: "Produced in Austria" and "Produced in the EU". (2) The price attribute was defined in accordance with the study by Weinrich and Elshiewy (2019), and the prices used in this experiment are 2.19 €, 2.79 €, 3.39 € and 3.99 € (each for a 200-gram pack). (3) We also included the attribute "flavor" (natural, salty and spicy based on the flavor varieties for algae crackers offered in Austria). (4) The attribute "production method" is a usual attribute in CBCA food studies, defined as "organic" and "conventional". Previous studies have already shown a close connection between locally as well as organically produced food with sustainability in the perception of consumers (Hempel and Hamm, 2016; Weinrich and Elshiewy, 2019; Zepeda and Deal, 2009). (5) Finally, there are two packaging opportunities for algae crackers, plastic and paper packaging (Raheem, 2013). Table 1 gives an overview of the included attributes and attribute levels. To keep the study design realistic, forbidden product attribute combinations (e.g., organic at lowest price level) were included (Table 2) and respondents had the possibility to refrain from choosing a product if none of the presented options met their expectations (no-choice option).

Table 1.
Examined attributes and their characteristics.

Attributes	Attribute levels
Origin	1. Produced in Austria
	2. Produced in EU
Price	1. 2.19 €
	2. 2.79 €
	3. 3.39 €
	4. 3.99 €
flavor	1. Natural
	2. Salt
	3. Spicy
Production method	1. Organic
	2. Non-organic
Packaging	1. Plastic
	2. Paper

Table 2.
Prohibited combinations of characteristics in profile design.

Forbidden combinations	Origin	Price	Production method
Combination 1	Produced in Austria	2.19 €	Organic
Combination 2	Produced in EU	3.99 €	Conventional

Step (iii): Consequently, out of 96 possible combinations (possible products), and considering the unused combinations, 10 different profiles were generated by means of the Microsoft add-in XLSTAT V2020.3.1.1 (Table 3) (reduced CBCA study design). In general, the number of profiles must always be lower than the number of comparisons and the number of profiles per comparison (XLSTAT, 2020).

Table 3.
CBCA stimuli design (XLSTAT, V2020.3.1.1).

Observations	Origin	Price	Flavor	Production method	Packaging
Profile 1	Produced in EU	3.99 €	Salty	Organic	Paper
Profile 2	Produced in Austria	2.19 €	Salty	Conventional	Plastic
Profile 3	Produced in EU	2.19 €	Natural	Conventional	Paper
Profile 4	Produced in Austria	3.39 €	Natural	Organic	Paper
Profile 5	Produced in EU	2.19 €	Spicy	Organic	Plastic
Profile 6	Produced in EU	3.39 €	Spicy	Conventional	Plastic
Profile 7	Produced in Austria	2.79 €	Salty	Organic	Plastic
Profile 8	Produced in EU	2.79 €	Natural	Conventional	Plastic
Profile 9	Produced in Austria	3.99 €	Natural	Conventional	Plastic
Profile 10	Produced in Austria	2.79 €	Spicy	Conventional	Paper

In accordance with the CBCA conducted by Weinrich and Elshiewy (2019), 12 choice sets of 4 stimuli each and an additional "no-choice" option were presented to participants. The possibility to choose the "no-choice" answer is closer to real market conditions; the respondents did not feel forced to choose between the given options simulating real shopping behavior where consumers tend to not buy a food product if the presented alternatives do not meet their demand. For instance, choice 1 consisted of the following profiles (Table 3): Choice 1: profile 2, choice 2: profile 6, choice 3: profile 10, choice 4: profile 7, choice 5: no choice option (0) (see Appendix for graphical design and trial plan).

Data were collected via an online survey in 2021. The questionnaire including the graphically designed choice were developed by means of the online platform LimeSurvey. In accordance with Weinrich and Elshiewy (2019), who used a minimum sample size of approximately 300 participants per country (Germany 315, Netherlands 310, France 315), the intended sample size for Austria was set at 300. After a pre-test, a total of 451 participants returned data, 301 were successfully completed and fulfilled all requested pre-conditions (responsible for shopping for the family, living in Austria). After eliminating some more data sets (e.g., due to consistently using the no-choice option), 278 cases could be used to approximate CBCA part-worth utilities. However, the sample structure does not correspond to the overall Austrian population (more females, younger, urban, higher educated; Table 4). Therefore, the approximations deliver non-transferable results, and representativeness is limited (convenience sample).

Table 4.
Demographic profile of respondents.

		Sample valid %	Austria % [a]
Gender	Male	28	51
	Female	72	49
Age	Up to 29	72	33
	30 to 44	21	20
	45 to 59	4	23
	60 and older	3	24
Place of residence	Rural	20	47
	Urban	80	53
Education	Compulsory school	3	18
	Apprenticeship/middle school	31	49
	High school diploma, university	66	33
Income per month	Mean individual income	estimated 1760 to 2185	1887

n = 278; [a] Statistics Austria; https://www.statistik.at

4 Results

At the beginning of the survey, the respondents were asked to indicate their agreement with selected statements concerning microalgae food products on a scale from 1 (total disagreement) to 7 (total agreement). The respective outcome can be taken from Table 5 and refers to the total sample with a maximum of 345 valid answers and the proportion of the sample with valid CBCA results (n = 278); the differences in means are negligible and didn't really change if only the CBCA sample is analyzed (Table 5). In general, the perception of respondents concerning microalgae food are mostly on an intermediate level. However, as we can learn from the first three items (statements S1 to S3), the

differences in the agreement of the respondents seem to be mainly due to product characteristics (intermediate WTP for microalgae food products, but much higher for regional/organic microalgae food).

In general, respondents are quite interested in novel food (S13); microalgae food is considered to be a more sustainable (S11) and also healthy (S4 and S7) food alternative. Besides texture/taste (S6), there seems to be no extreme tendency in the answers of the respondents (respondents mostly reject the statement that they will not like the texture or taste of microalgae food products). It will be interesting to compare these results with the outcome of the CBCA; e.g., if there is a correlation between the acceptance of higher prices and the approximated WTP according to the CBCA.

Table 5.
Arithmetic mean values of the consumer preference statements

Statement		Statement	Mean CBCA sample, n = 278	Mean total sample	Standard deviation total sample	n total sample
S1	General WTP	I would also be prepared to pay higher prices for food made from algae.	4.08	4.10	1.54	336
S2	WTP for regional prod.	I would spend more money on algae food that was produced regionally.	5.24	5.28	1.47	340
S3	WTP for organic prod.	I would spend more money on algae food that was produced organically.	5.18	5.18	1.50	338
S4	Vegetarian / vegan diet	I think that a vegetarian or vegan diet is beneficial for the human organism.	5.00	5.00	1.80	345
S5	Price	I think meat substitutes made from algae are too expensive.	4.09	4.07	1.36	292
S6	Texture/Taste	I think I would not like the texture or taste of algae food products.	3.32	3.32	1.64	330
S7	Health	I believe that the consumption of algae food has a positive effect on my health.	5.06	5.02	1.29	329
S8	Appearance	The appearance of algae food would be important to me.	4.61	4.56	1.65	343
S9	Packaging	The packaging of algae food would be important to me.	4.95	4.98	1.59	342
S10	Variety	When buying algae food, it would be important for me to have a wide choice.	4.27	4.25	1.45	333
S11	Sustainability	I believe that the consumption of algae food has a positive impact on the environment and climate.	5.45	5.45	1.34	327
S12	Substitutability	I think food made from algae is a good meat substitute.	4.21	4.20	1.57	324
S13	Novelty	I am interested in new and innovative foods.	5.66	5.66	1.31	345
S14	Curiosity	I find food from algae an exciting topic that interests me personally.	5.02	5.00	1.73	342
S15	Preparation	I do not know how to prepare meals with food made from algae.	5.20	5.25	1.71	343
S16	Future prospect	I believe that the consumption of algae food in Austria will increase in the coming years.	4.89	4.90	1.41	338

1 = do not agree at all … 7 = very much agree

The following CBCA analysis refers to the CBCA sample (n = 278). As mentioned above, the approximations of the importance of the different product attributes and of the part-worth utilities of each attribute level were done on an individual level per respondent by means of Hierarchical Bayes estimations. The most important attributes responsible for the choices of the respondents are the production method (0.267) and price (0.256). Origin (0.206) and packaging (0.173) are also quite important, flavor seems to be less relevant (0.098). However, the results are quite heterogeneous considering the minimum and maximum values and standard deviation in Table 6 (this issue would require further considerations, e.g., cluster analysis; however, we refrain from including the respective results in this contribution as it leads us beyond the study goal). Confirming a one-sampled t-test, all attributes are significantly higher than 0.

Table 6.
Importance of attributes.

Attribute	Minimum	Maximum	Mean	Standard deviation	t	95% confidence interval lower	95% confidence interval upper
Origin	0.001	0.596	0.206 ***	0.105	33.05	19.65	22.14
Price	0.021	0.816	0.256 ***	0.140	29.77	23.80	27.17
Flavor	0.005	0.536	0.098 ***	0.065	28.64	8.76	10.05
Production method	0.003	0.556	0.267 ***	0.139	32.67	25.49	28.76
Packaging	0.000	0.504	0.173 ***	0.121	23.35	15.64	18.52

N = 278; *** sig. < 0.001

Concerning the part-worth utilities of the attribute levels, the results are in accordance with our expectations. Produced in Austria, the lowest price level (2.19 €) and organic production are much better evaluated compared to production in EU, highest price (3.99) and conventional production. Here too, the distribution of part-worth utilities indicates that a further analysis of the individual approximations might be necessary (Table 7). Confirming a one-sampled t-test, all attribute levels are significantly different from 0, despite attribute level "spicy".

Table 7.
Part-worth utilities of attribute levels.

Attribute level	Minimum	Maximum	Mean		Standard deviation	t	95% confidence interval lower	95% confidence interval upper
Origin—produced in Austria	-0.759	3.499	1.603	***	0.931	29.11	1.52	1.74
Origin—produced in EU	-3.499	0.759	-1.603	***	0.931	-29.11	-1.74	-1.52
Price—2.19	-1.648	5.167	1.601	***	1.351	19.41	1.44	1.77
Price—2.79	-0.951	2.706	1.140	***	0.719	26.34	1.07	1.24
Price—3.39	-3.639	1.589	-1.305	***	1.125	-19.15	-1.45	-1.18
Price—3.99	-3.325	1.419	-1.435	***	0.835	-28.68	-1.55	-1.35
$\beta_{price} = -1.926$ ($R^2 = 0.87$)							-1.91	-1.96
Flavor—natural	-1.996	1.796	0.121	***	0.611	4.12	0.07	0.21
Flavor—salty	-1.518	1.833	-0.084	*	0.562	-2.13	-0.14	-0.01
Flavor—spicy	-2.219	3.514	-0.037		0.892	-1.42	-0.17	0.03
Production method—conventional	-4.459	1.220	-2.043	***	1.309	-26.34	-2.23	-1.92
Production method—organic	-1.220	4.459	2.043	***	1.309	26.34	1.92	2.23
Packaging—paper	-0.748	3.446	1.217	***	0.905	21.92	1.10	1.32
Packaging—plastic	3.446	0.748	-1.217	***	0.905	-21.92	-1.32	-1.10

N = 278; * sig. < 0.05; *** sig. < 0.001

To approximate WTP for changed attribute levels, theoretical considerations are based on compensation via price changes. In other words, consumers will be willing to pay more/less to obtain a superior/inferior attribute characteristic instead of another attribute (Breidert and Hahsler, 2007). If the overall part-worth utility of the product increases, the price of the product can increase as well to reach the same utility level (and vice versa). The difference then equals the approximated WTP confirming the above formula ratio $-\beta_1/\beta_{price}$. The approximation of WTP was done on an aggregate level, as linearity is required which is not always the case on an individual level; in this study, the approximation of β_{price} worked well (R^2 = 0.87; Table 7).

Mean part-worth for organic production is 2.04. For this attribute the highest WTP is approximated with WTP = +1.06 €, followed by Austrian origin WTP = +0.83 €. For all other attributes, WTP approximations are similar. WTP for origin, production method and packaging are rather high considering the overall price levels (up to +1.06 €; Table 8) and very low for the attribute flavor. Even though WTP might be overestimated, it clearly shows that also in the case of microalgae, origin and production method are essential attributes which might be surprising for this non-domestic product category. Consumers are in general willing to pay more for organic, domestic and paper packaged microalgae products.

Table 8.
Willingness to pay.

Property characteristics	WTP [a]
Origin—produced in Austria	+0.83 €
Origin—produced in EU	–0.83 €
Production method—organic	+1.06 €
Production method—conventional	–1.06 €
Packaging—paper	+0.63€
Packaging—plastic	–0.63 €
Flavor—natural	+0.06 €
Flavor—salty	–0.04 €
Flavor—spicy	–0.02 €

[a] approximated on an aggregated level (basis: means of CBCA sample)

As we can see from Table 9, there are some significant correlations of selected perception statements (only WTP relevant statements S1 to S3 were used for this analysis). If the price attribute is more important for respondents (price sensitive buyers), the self-assessed WTP is lower; the correlation coefficients (Pearson's *r*) are all negative and significant; in particular, *r* reaches an intermediate level for WTP for regional and organic food (*r* = –0.338 and –0.326, respectively). For production method attribute the opposite is true: the more important the production method is, the higher the self-assessed WTP confirming S1 to S3. *r* amounts to 0.272, 0.220 and 0.399, respectively; all significant.

Table 9.
Correlation between WTP-statements and CBCA approximations.

		Price levels				Importance attribute		
		2.19 €	2.79 €	3.39 €	3.99 €	origin	prod. method	price
S1: I would also be prepared to pay higher prices for food made from algae.	Pearson's r Sig. N = 265	–0.134* 0.029	0.183** 0.003	0.114 0.063	–0.093 0.130	0.058 0.348	0.272** 0.000	–0.178** 0.004
S2: I would spend more money on algae food that was produced regionally.	Pearson's r Sig. N =268	–0.330** 0.000	0.172** 0.005	0.251** 0.000	0.048 0.429	0.175** 0.004	0.220** 0.000	–0.338** 0.000
S3: I would spend more money on algae food that was produced organically.	Pearson's r Sig. N = 266	–0.310** 0.000	0.226** 0.000	0.259** 0.000	–0.039 0.525	0.012 0.850	0.399** 0.000	–0.326** 0.000

* Sig. < 0.05; ** Sig. < 0.01

Including the price levels in the analysis, this interpretation holds: The more price sensitive respondents are, the less they agree to the WTP statements S1 to S3.

5 Discussion and Conclusion

Concerning the first research question regarding the importance of selected attributes for microalgae food products for consumers (including the utility of attribute levels), the results of the CBCA show that the attribute "production method" is the most important attribute with an overall importance of 26.7% (maximum part-worth utility for the attribute level "organic"), followed by price (25.6%; as expected, the lowest price has the highest part-worth utility), origin (20.6%; maximum part-worth utility for domestic origin), packaging (17.3%; paper packaging) and taste (9.8%; almost no differences between "spicy", "salt", "sweet"). Even though it is not really comparable with other studies from the literature, it was surprising that the price, in particular, was so important in our study, whereas in other studies focusing on functional foods the price attribute was least important of all attributes included in the CBCA (Annunziata and Vecchio, 2013). To our knowledge, this is the first study in a highly developed consumer market, evaluating the importance of very concrete product features of microalgae by means of a DCE. There are studies available covering, e.g., consumer knowledge and attitudes (Lafarga et al., 2021) and the general benefits and opportunities for human nutrition (Chen et al., 2022). With our results, food processors are able to focus on the importance of specific product features (organically produced microalgae at moderate price levels). Further, the overall WTP was assessed: +1.90 € for Origin Austria compared to products imported from the EU; +2.42 € for organically produced and +1.44 € for paper packaging (in comparison to plastic packaging). This delivers valid answers for the second research question of the study. The approximations seem to be quite realistic which is in line with Krystallis and Chryssohoidis (2005) revealing that the WTP measured by a conjoint analysis is more realistic than methods where consumers are directly interviewed.

Considering the outcome of the perception part of the study (agreement to statements S1 to S16), it is plausible to consider the respondents of this study as being above average ready to accept novel food. Therefore, the following conclusions that are based on a convenience sample might be true for parts of the consumers (interested in and ready to adopt food innovations/novel food products).

However, there are some limitations and issues which have to be taken into account when interpreting these results. The sample structure of this study does not correspond to the Austrian population as they were collected by means of a convenient sample; they can therefore not be considered to be representative (Ball, 2019). Compared to our study, Weinrich and Elshiewy (2019) offer better representativeness and data quality with a significantly larger sample (n = 940). The sample size is however also due to the fact that Weinrich and Elshiewy (2019) compared three countries (Germany, Netherlands, France). The sample size for the present study is therefore more or less comparable to Weinrich and Elshiewy (2019). The lack in data quality however reduces the quality of our outcome, and in future research better representativeness should be achieved.

There has been a five-fold increase in microalgae production in food and feed since the early 2000s (Vigani et al., 2015). However, it is still a niche market and the commercial production of microalgae as an alternative source of proteins, fatty acids and carbohydrates is still an industry in its infancy (Vigani et al., 2015). Nevertheless, we see that improvements in the production technology can be implemented to enable a more sustainable microalgae production in the future (Grahl et al., 2018). These market developments might be further boosted as the sector for microalgae products, either as final product or biomass, is expanding with start-ups and big enterprises indicating their interest on a global scale (Caporgno and Mathys, 2018). If we accept that the respondents in our study have a rather positive attitude and perception of microalgae in human nutrition, the respective results may be considered valid for the core target group within this market rather than the general population. We can see that at least for this target group, microalgae-based food products should be produced regionally and organically (sustainable packaging such as paper is preferred too). In this case, the products can be sold at a significant price premium. This is in accordance with Weinrich and Elshiewy (2019). We approximated an even higher WTP for organic production compared to regional production, a slight contradiction to the literature (Hempel and Hamm, 2016; Zander and Hamm, 2010; Zepeda and Deal, 2009). However, to identify and evaluate product characteristics that are relevant for the broader public, or, more generally speaking, reaching the mass market with novel food based on microalgae, more in-depth research will be beneficial implementing appropriate empirical designs (such as CBCA in our study) and applying high-quality data. Through this approach, it should be possible to gain an in-depth understanding of consumer behavior in the microalgae market and also to convince consumers to integrate microalgae into their daily diet. At least, they might overcome the refusal or avoidance to eat novel food, in general known as food neophobia, one of the most important obstacles for novel food products to be successful in the food market.

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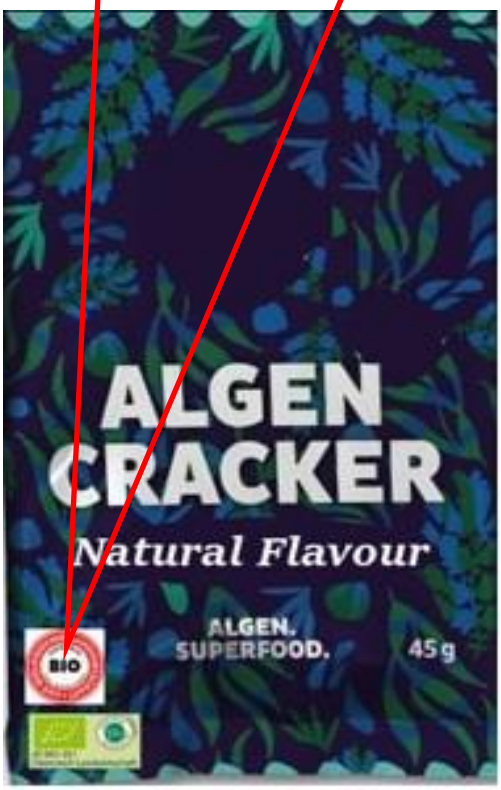
Appendix — Graphical design and trial plan

Graphical design of stimuli



Example choice (incl. no-choice option)

Trial plan for conjoint analysis with XLSTAT

Comparison	Choice 1	Choice 2	Choice 3	Choice 4	"no-choice"
1	2	6	10	7	0
2	9	3	5	4	0
3	4	5	1	6	0
4	2	7	8	3	0
5	3	4	2	1	0
6	5	7	6	8	0
7	7	1	10	5	0
8	8	2	4	6	0
9	10	8	7	4	0
10	6	1	3	9	0
11	5	10	9	2	0
12	1	9	8	10	0