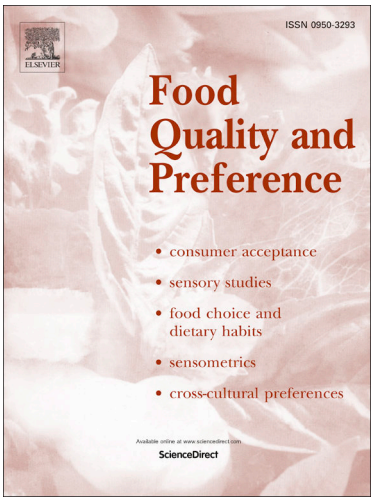
Journal Pre-proofs



'Edible seaweeds' as an alternative to animal-based proteins in the UK: Identifying product beliefs and consumer traits as drivers of consumer acceptability for macroalgae

Rochelle Embling, Louise Neilson, Tennessee Randall, Chloe Mellor, Michelle D. Lee, Laura L. Wilkinson

PII: S0950-3293(22)00088-X
DOI: https://doi.org/10.1016/j.foodqual.2022.104613
Reference: FQAP 104613

To appear in: *Food Quality and Preference*

Received Date: 20 July 2021
Revised Date: 6 April 2022
Accepted Date: 18 April 2022

Please cite this article as: Embling, R., Neilson, L., Randall, T., Mellor, C., Lee, M.D., Wilkinson, L.L., 'Edible seaweeds' as an alternative to animal-based proteins in the UK: Identifying product beliefs and consumer traits as drivers of consumer acceptability for macroalgae, *Food Quality and Preference* (2022), doi: https://doi.org/10.1016/j.foodqual.2022.104613

'Edible seaweeds' as an alternative to animal-based proteins in the UK: Identifying product beliefs and consumer traits as drivers of consumer acceptability for macroalgae.

Rochelle Embling [a], Louise Neilson [b], Tennessee Randall [a], Chloe Mellor [a], Michelle D. Lee [a], & Laura L. Wilkinson [a]

[a] Department of Psychology, College of Human and Health Sciences, Swansea University, Swansea, SA2 8PP, UK.

[b] BIC Innovation Ltd, Pencoed Technology Park, Pencoed Technology Centre, Pencoed, Bridgend, CF35 5HZ.

Corresponding author: Rochelle Embling, Department of Psychology, College of Human and Health Sciences, Swansea University, Swansea, SA2 8PP, UK. Phone: 01792 29 5279. Email: rochelle.embling@outlook.com.

Dr Louise Neilson, Email: Louise.Neilson@bic-innovation.com

Tennessee Randall, Email: tennesseer-20@hotmail.co.uk

Chloe Mellor, Email: 953811@Swansea.ac.uk

Professor Michelle D. Lee, Email: m.d.lee@swansea.ac.uk

Dr Laura Wilkinson, Email: l.l.wilkinson@swansea.ac.uk

Availability of data and materials: The datasets generated and analysed during the current study are available in the Open Science Framework repository, https://osf.io/jy897/.

Declaration of interests: none.

Short title: Consumer acceptability of seaweed-based foods

Abstract

Edible macroalgae (i.e., 'seaweeds') are a nutritious and sustainable alternative to animal-based proteins. However, consumption of seaweeds in Western countries remains low, and little is known about individual drivers of acceptance. The aim of this study was to further explore the consumer acceptability of seaweed-based food products in the UK. In an online study (N = 476), participants were presented with a general description of edible seaweeds, and descriptions of seaweed-based food products (e.g., 'seaweed burger'). Participants were asked to rate beliefs about product attributes, and reported acceptance in terms of liking, willingness to try, willingness to buy, and readiness to adopt as a meat alternative. It was predicted that positive beliefs about seaweed-based products would be significantly associated with greater acceptance, and that seaweed-based products would be more favourable than a general description of seaweeds. Supporting study hypotheses, structural equation modelling showed that positive beliefs about taste/ edibility and familiarity significantly predicted acceptance ($p < .01$). Taste/ edibility was higher for seaweed-based products compared to a general description of seaweeds ($p < .001$), and perceiving foods to be tasty and familiar mediated the negative effect of food neophobia on consumer acceptance ($p < .05$). Other product beliefs – including cost, healthiness, and sustainability – were relatively poor predictors of acceptance ($p > .05$). These results support the consumer acceptance of seaweeds, and identify scope for utilising specific attributes of seaweeds (as drivers of acceptance) in future product development.

Keywords: consumer acceptance, algae, seaweeds, meat substitute, plant-based, consumer perception

1. Background

Dietary intake of protein is a long-standing recommendation in nutritional guidelines (Mozaffarian & Ludwig, 2010). In recent years, the consumption of animal-based proteins (including meat and dairy products) has substantially increased worldwide, such that the intake of animal-based proteins now exceeds recommended amounts in developed countries (Godfray et al., 2018; Stoll-Kleemann & O'Riordan, 2015). The overconsumption of meat is known to negatively impact the environment and food security, as well as consumer health (Godfray et al., 2018; Rust et al., 2020; Stoll-Kleemann & O'Riordan, 2015). To combat these effects, nudging consumers towards choosing plant-based (e.g. soy-based substitutes) and other alternative proteins (e.g. single cell proteins) as part of a 'plant-forward diet' is one strategy that has been recommended to reduce the consumption of animal-based proteins (Rust et al., 2020).

Edible macroalgae – more commonly known as 'seaweeds' – have been identified as a promising alternative to animal-based proteins. As a nutritious food source, seaweeds are generally high in dietary fibres, vitamins, and minerals, and low in dietary fat content (Cherry et al., 2019; Circuncisão et al., 2018; Fleurence et al., 2012). Across species, the protein content of green seaweeds is estimated to be 10 – 25% of its dry weight, increasing to up to 47% for red seaweeds (Cherry et al., 2019). Harvesting seaweeds is also considered to be a sustainable practice, as seaweeds can be farmed in large quantities without resources required for other plant-based alternatives, such as fertiliser, freshwater, and expanses of agricultural land (Mahadevan, 2015). From a product development perspective, seaweeds benefit from having an already well-established consumer market as a food source, particularly in Asia (Fleurence et al., 2012). However, despite some evidence of traditional use, seaweeds remain a food item with relatively low present-day consumption rates in most Western countries

(Birch et al., 2019; Chapman et al., 2015; Fleurence et al., 2012; Labbe et al., 2019; Losada-Lopez et al., 2021; Palmieri & Forleo, 2020).

In addition to other Western countries, there appears to be an emerging market for seaweeds and seaweed-containing products in the UK (Adams, 2016; Birch et al., 2019; Bouga & Combet, 2015). In some parts of the country, consuming seaweeds in traditional recipes has continued to the present day. For example, in Wales, purple laver (*Porphyra umbilicalis*) is used to make 'laverbread', a seaweed-based puree that is often served with other seafoods or meat (Adams, 2016; Mahadevan, 2015). A growing range of seaweeds and seaweed-based food products – including sushi, seaweed sheets, breads, confectionary, condiments, pasta, soups, snacks, and drinks – have also been made available to consumers in both large supermarkets and specialist retailers, with the majority of products being UK sourced (Bouga & Combet, 2015).

Despite the increasing availability of seaweeds and its potential use as a nutritious and sustainable food source, to our knowledge, little is known about the acceptability of seaweeds for UK consumers. Therefore, we invited consumers to complete an online survey about their beliefs regarding seaweeds and seaweed-based food products, and asked them to rate acceptability in terms of liking, willingness to try, willingness to buy, and readiness to adopt as a meat alternative. The aim of this study was to further explore the consumer acceptability of seaweed-based food products in the UK, and help identify specific drivers of acceptance for seaweeds relating to both product beliefs and consumer traits.

2. Hypotheses and supporting theoretical framework

2.1. The influence of product beliefs on consumer acceptability

Previous research has generally reported a high willingness to try/ eat seaweeds among consumers in Western countries (Birch et al., 2019; Losada-Lopez et al., 2021; Palmieri & Forleo, 2020, 2021; Wendin & Undeland, 2020). In turn, this acceptability of seaweeds is often accompanied by positive evaluations of product attributes. For example, after taste-testing sample dishes, consumers tended to report a moderate-to-strong liking of seaweeds, with positive descriptions of the flavour and texture (e.g. 'nutty' and 'soft') (Chapman et al., 2015; Lamont & McSweeney, 2021). Consumers have also perceived seaweeds to be 'tasty', 'healthy' and 'good for the environment' when evaluating potential food products (Wendin & Undeland, 2020). As a collective construct, such dimensions have been identified as having a considerable effect on acceptability of 'novel' meat substitutes, including insects and blended meat/ plant-based products (Koning et al., 2020; Lang, 2020). However, the relative importance of *individual* product attributes to consumer acceptability for seaweeds warrants further exploration, as 'taste' and 'healthiness' in particular have recently been highlighted as key product-related drivers of acceptance for other alternatives to animal-based proteins (Onwezen et al., 2021). Therefore, it was predicted that more positive perceptions of seaweed-based food products would be significantly associated with greater acceptance ratings for these foods as individual predictors of acceptability (H1).

2.2. The influence of a 'product' context on consumer acceptability

Rather than presenting seaweeds as an edible food in general or in isolation, using seaweeds as an additional ingredient in other *well-known* products can benefit consumer

acceptance (Birch et al., 2019; Chapman et al., 2015). This is particularly important to consider given that less familiarity with eating seaweeds, and greater trait levels of food neophobia and food technology neophobia (avoidance of novel foods and foods produced with novel food technologies, respectively), have been identified as significant barriers to consumers accepting seaweeds as a food source (Birch et al., 2019; Losada-Lopez et al., 2021; Palmieri & Forleo, 2020).

We also note that consideration of the meal/ product context can be helpful to further product development and placement of a particular food source within a consumer market. Framing a food source as a component within a specific meal/ product context has been shown to enhance acceptability for other alternatives to animal-based proteins relative to presenting the food source 'individually' (e.g. 'chickpea burger' vs. 'chickpeas') (Possidónio et al., 2021). Acceptance can even differ across prospective meals/ items for the same food source (Elzerman et al., 2011, 2015; Grahl et al., 2018; Possidónio et al., 2021), as consumers may perceive some product contexts to be more appropriate for consumption than others (Elzerman et al., 2011, 2015). However, noticeably fewer studies have explored the acceptability of specific seaweed-based food products relative to 'seaweeds' more generally (Chapman et al., 2015; Lamont & McSweeney, 2021; Wendin & Undeland, 2020), and preference for items appears to differ considerably between consumer segments (Chapman et al., 2015; Wendin & Undeland, 2020).

For these reasons, it was predicted that Food ratings would be significantly higher (or more positive) when responding to hypothetical seaweed-based food products compared to a general text description of seaweeds as a food source (H2).

2.3. The influence of consumer traits and food-related attitudes on consumer acceptability

There is evidence that acceptability for alternatives to animal-based proteins – including seaweeds – differs across consumer profiles (Onwezen et al., 2021). In addition to considering effects of food neophobia and food technology neophobia (see **section 2.2** above), studies within this area of research typically explore the role of other food-related attitudes in promoting consumer acceptance, such as attitudes towards the healthiness, convenience, and environmental impact of food, as well as the importance that consumers place on nutritional and sensory qualities of meat (Gómez-Luciano et al., 2019; Verbeke, 2015). Applying such an approach to the consumption of seaweeds, Birch and colleagues (Birch et al., 2019) found that consumers had a greater likelihood of eating seaweeds in the future if they were more health conscious and had a tendency toward 'convenient' snacking behaviour, whereas concerns about food safety and ethics (including sustainability) had little impact on acceptance. However, research also suggests that the impact of these attitudes on consumer acceptance can differ across consumer profiles that incorporate *perceptions* of consuming seaweed, particularly according to whether these beliefs are positive or negative (Palmieri & Forleo, 2020). Therefore, considering the influence of consumer traits on acceptance, in conjunction with the role of product beliefs, can provide further insight into potential drivers for seaweeds in a specific sample. In this study, consumer traits and food-related attitudes were then explored as factors that interact with food ratings (for product attributes) to predict consumer acceptance (H3).

3. Method

3.1. Study design

Using a cross-sectional design, this study examined associations between beliefs about seaweed-based food products (measured across 10 dimensions), and four acceptability ratings (liking, willingness to try, willingness to buy, and readiness to adopt as a meat alternative). Food ratings were first collected in response to a general text description of seaweed as a food source, followed by text descriptions/ photographs of six hypothetical seaweed-based food products presented in a randomised order determined by the survey software 'Qualtrics' (Qualtrics, Provo, UT) (see **section 3.4** for details). Three questions were included as attention checks throughout the survey (on two occasions, participants were asked to "please select 'not at all' by dragging the slider all the way to the left", and on the third occasion they were asked to "please select 'strongly agree'" on a Likert scale). Questionnaire measures used to assess general eating-related traits and beliefs were collected after participants had responded to all food descriptions (see **section 3.5** for details). Study methods and planned data analyses were preregistered on the Open Science Framework (OSF) before data collection had begun, and structural equation modelling procedures were preregistered before the proposed model was conducted (https://osf.io/jy897/).

3.2. Participants

Participants were recruited to complete the study in March 2021 via 'Prolific' (https://www.prolific.co). Participants were directed to the survey using an anonymous link to

'Qualtrics'. Before completing a consent form (to provide informed written consent), participants were presented with an information sheet and informed that the aim of the research was to "explore consumer beliefs about a potential new food product". Participants completed the study in approximately 20 minutes, and were compensated for their time with a payment of £2.50 on Prolific (following the platform's guidelines on fair pay). The study was approved by the Department of Psychology Research Ethics Committee at Swansea University.

Following Fritz and MacKinnon (2007), it was estimated that 462 participants were required to detect a mediated 'small' effect using bias-corrected bootstrap approaches ($1-\beta = 0.80$). Data collection was then stopped when 535 responses to the survey had been recorded to account for unusable data (e.g., duplicate responses from the same participant ID, participants who did not finish the survey). Participants were eligible to be included in the study if they were currently living within the UK, and if they self-identified as having normal or corrected-to-normal vision. All participants were 18 years old or older. Participants were excluded from the study if they reported having a current or history of eating disorders, if they reported any food allergies or intolerances that might limit the applicability of food descriptions used in the study, and if they failed multiple attention checks. After removing ineligible responses, 476 participants were included in the sample.

3.3. 'Seaweed' and 'seaweed-based' food descriptions

Participants were presented with seven food descriptions (see **Table 1**). Each product description framed seaweeds as a 'protein-rich' food source. In the first description, participants were provided with examples of different edible seaweeds. For each of the six

remaining descriptions, participants were provided with an example of a hypothetical seaweed-based food product containing seaweeds as a complimentary ingredient to other identifiable food components. Hypothetical food products were chosen to represent different uses of seaweeds as a food source (i.e., as an ingredient in snacks, main dishes, beverages, and sweet foods). An example photograph of each item was included for hypothetical food products to demonstrate a potential serving. Photographs did not contain any identifiable product labels or additional information about the product, with the exception of flavourings included on juice drinks (see **Supplementary methods A.1.** for alt-text image descriptions).

[Insert **Table 1** about here]

3.4. Food ratings

3.4.1. Beliefs about 'seaweed' and 'seaweed-based' food products

Following Possidónio et al. (2021), participants rated their beliefs about seaweed and seaweed-based food products along 10 characteristic dimensions; taste, edibility, healthiness, caloric content, naturalness, degree of processing, expensiveness, ethics, sustainability, and familiarity. All ratings were provided in response to food descriptions using a series of 100-mm visual analogue scales anchored 'Not at all'– 'Extremely', with the characteristic of interest included in the anchor label (e.g., 'Not at all appetising'– 'Extremely appetising' for taste). A 'neutral' label was included at the midpoint of each scale to guide responding.

212 **3.4.2. Consumer acceptability**

213

214 In line with previous studies on the acceptance of alternatives to animal-based
215 proteins (Gómez-Luciano et al., 2019; Verbeke, 2015), participants were asked to rate their
216 readiness to adopt as a substitute for meat ("I would be prepared to eat… as a substitute for
217 meat"), willingness to try ("Would you personally be willing to try…?"), and willingness to
218 buy ("Would you personally be willing to purchase…?"). They were also asked to rate their
219 expected liking ("I expect to like…"). Ratings were provided in response to each food
220 description using a series of 100-mm visual analogue scales, with the anchors 'Not at all –
221 Extremely'/ 'Definitely not – Definitely yes'. A neutral label was included at the midpoint of
222 each scale to guide responding ('Neither agree nor disagree'/ 'Might or might not').

223

224 **3.5. Consumer traits and demographics**

225

226 In line with previous studies on the acceptance of alternatives to animal-based
227 proteins (Gómez-Luciano et al., 2019; Verbeke, 2015), participants completed six short
228 questionnaires to assess general attitudes and beliefs about foods. Participants completed the
229 'Food Neophobia Scale' (FNS; 10 items) (Pliner & Hobden, 1992) as presented in Gómez-
230 Luciano et al. (2019), 'Food Technology Neophobia Scale' (FTNS; 13 items) (Cox & Evans,
231 2008), 'General Health Interest' subscale (8 items) to assess interest in health benefits of
232 foods (Roininen et al., 1999), the 'CONVOR scale' (as reported in the 'final' version; 6
233 items) to assess convenience orientation relating to food choices (Candel, 2001), beliefs
234 regarding the environmental impact of foods (5 items) (Gómez-Luciano et al., 2019), and
235 beliefs about the benefits of consuming meat (6 items) (Gómez-Luciano et al., 2019). To

check for potential social-desirability bias in participant responses, participants also completed the 'impression management' subscale (8 items) from the 'Balanced Inventory of Desirable Responding Short Form' (BIDR-16) (Hart et al., 2015). Across all questionnaires, participants provided responses on a 5- or 7-point Likert-scale ranging from "Strongly disagree" to "Strongly agree". Higher scores indicated greater levels of the respective trait (e.g., increased food neophobia, increased interest in the health of foods).

Participants were asked to provide demographic information including their age, gender, country of residence, highest completed qualification, and employment status. Participants were also asked to report details about their current diet. This included the type of diet followed (i.e., whether or not their diet included meat and animal products), the length of time spent following their current diet, and reasons for following their current diet in an optional open-text field. At the end of the study, participants self-reported their height and weight using drop-down lists to enable calculations of body mass index (BMI). They were asked to describe their beliefs about the aim of the study in an open-text field before they were presented with a debrief form.

3.6. Data analysis

When providing food ratings, 189 participants rated 5 instead of 6 hypothetical foods due to a function error (selection was randomised). No significant outliers were detected for product beliefs or consumer acceptability variables (3 x IQR). Though it did not warrant exclusion from the study, 23 participants failed a single attention check. Unless otherwise stated, all food ratings (relating to product beliefs and consumer acceptance) were collapsed across hypothetical seaweed-based food products by calculating the mean.

To check associations between identified predictors and consumer acceptance for hypothetical seaweed-based food products, all food ratings were entered into a bivariate correlation matrix. As the Shapiro-Wilk test showed that data for food ratings were not normally distributed ($p < .005$), an appropriate non-parametric test was used to calculate coefficients (Spearman's Rho). These analyses showed that 'Taste' and 'edibility' ($r_s = .768$, $p < .001$), and 'ethics' and 'sustainability' ($r_s = .822$, $p < .001$), were highly correlated. As such, composite scores for these beliefs were included in data analyses (mean score across variables). See **Supplementary Table A.1.** for all correlations between predictors, and **Supplementary Figure A.1.** for correlations between predictors and consumer acceptance.

A one-way repeated measures MANOVA was used to test the hypothesis that product beliefs would be significantly higher (or more positive) when responding to hypothetical seaweed-based food products compared to a general text description of seaweeds as a food source (H2). 'Food description' was entered as a within-subjects factor with 7 levels (descriptions of algae/ seaweeds, energy bar, burger, pasta, sushi, juice drink, and baby sugar kelp), and ratings for product beliefs were entered as dependent variables. A one-way repeated measures MANOVA was also used to explore differences between individual hypothetical food products in terms of acceptability. 'Food product' was entered as a within-subjects factor with 6 levels (energy bar, burger, pasta, sushi, juice drink, and baby sugar kelp), and acceptability outcome measures were entered as dependent variables. Across analyses, Mauchly's test of sphericity was significant ($p < .001$), and the Greenhouse-Geisser correction was applied to within-subjects effects. Bonferroni-corrected pairwise comparisons were used as follow-up tests.

A two-step structural equation modelling analysis was used to identify product-related attributes as predictors of acceptability for hypothetical seaweed-based food products (H1), and explore potential interactions with consumer demographics and food-related attitudes

(H3). Following a recent theoretical framework of acceptability for meat substitutes and 'plant-forward' diets (Lang, 2020), consumer demographics and consumer values/ attitudes towards foods, food technologies, and relevant behaviours, were included as antecedent predictors of acceptability for seaweed-based food products. Consumer evaluations of product attributes were included as key mediating factors influencing acceptability for seaweeds. As such, both direct and indirect effects (via beliefs about product-related attributes) of consumer profiles on acceptability were explored (see **Figure 1**). For results of multiple linear regression analyses with each individual measure of acceptability as the outcome variable, see **Supplementary methods A.2.** and **Tables A.2 – 5**.

In line with recommendations and suggested cut-off values reported by Hair and colleagues (Hair et al., 2014, 2017), the reliability (Cronbach's alpha, McDonald's omega, composite reliability) and validity (average variance extracted [AVE], Fornell-Larcker criterion, heterotrait-monotrait ratios) of latent constructs was checked in step 1, and overall model fit indices were reported in step 2 (CFI [comparative fit index] and RMSEA [root mean square error of approximation]). Model parameters and item weights were estimated using the Maximum Likelihood (ML) estimator and adjusted using bias-corrected bootstrapping approaches (1000 samples). In step 1, up to 20% of items were dropped from analyses if factor loadings were < .50. In step 2, exogenous variables and intervening endogenous variables, that did not significantly influence endogenous variables, were removed as part of exploratory model trimming, and modification indices were used to explore post-hoc improvements to model fit by accounting for residual covariances within included factors (mi > 10). Indirect effects were deemed significant if $p < .05$, and if 95% confidence intervals did not cross zero.

Structural equation modelling was conducted using the 'Lavaan' syntax (Rosseel, 2012) in JASP v0.15. All other data analyses were conducted in IBM SPSS v26.

[Insert **Figure 1** about here]

4. Results

4.1. Participant characteristics

Participants included 325 females (68.3%), 150 males (31.5%), and one participant who identified their gender as non-binary. One participant reported that their identified gender was not assigned at birth, and one participant preferred not to say. Almost all participants followed a diet that contained meat or fish (93.3%), including 8.2% who had a flexitarian diet (i.e., mostly consumed a vegetarian diet but occasionally consumed meat/ fish), and 77.1% of participants reported that their current diet was lifelong. Most participants were resident in England (85.7%), followed by Scotland (7.8%), Wales (4.6%), and Northern Ireland respectively (1.9%). Most participants had received education to high-school (37.2%) or university-degree level (60.3%), with < 1% reporting no formal qualifications. The majority of participants reported being in full-time or part-time employment (58.0%), being self-employed (8.2%), retired (5.7%), or a student (12.4%). See **Table 2** for all other participant characteristics.

[Insert **Table 2** about here]

4.2. Differences in beliefs between descriptions of 'algae/ seaweed' and hypothetical seaweed-based food products

There was a significant MANOVA effect for food description (Pillai's Trace = .868, $F(48, 237) = 32.35$, $p < .001$, partial $\eta^2 = .868$), and significant differences were observed between food descriptions for all product beliefs (Greenhouse-Geisser corrected p's < .05). Bonferroni-corrected pairwise comparisons showed that algae/ seaweed was believed to be significantly less appetising than the energy bar, burger, pasta and sushi ($p < .001$); healthier than the energy bar, burger, sushi, and baby sugar kelp ($p < .05$); less calorific than the energy bar, burger, sushi, juice drink, and baby sugar kelp ($p < .001$); more natural than the energy bar, burger, pasta, sushi, and juice drink ($p < .001$); less processed than the energy bar, burger, pasta, sushi, and juice drink ($p < .001$); less expensive than the energy bar, burger, pasta, sushi, juice drink, and baby sugar kelp ($p < .001$); less familiar than the energy bar and sushi ($p < .001$); and more familiar than the baby sugar kelp ($p < .001$). There were no significant differences between algae/ seaweed and seaweed-based food products in terms of ethics/ sustainability ($p > .05$). See **Table 3** for descriptive statistics for food ratings.

4.3. Differences in acceptability between hypothetical seaweed-based food products

There was a significant MANOVA effect for hypothetical product type (Pillai's Trace = 0.633, $F(20, 265) = 22.830$, $p < .001$, partial $\eta^2 = .633$), and significant differences were observed between product descriptions for all acceptability measures (Greenhouse-Geisser corrected p's < .001). Bonferroni-corrected pairwise comparisons showed that readiness to

adopt the burger and sushi as meat substitutes was significantly higher than readiness to adopt for all other foods ($p < .001$); and readiness to adopt the baby sugar kelp and juice drink was significantly lower ($p < .001$). Willingness to try and willingness to buy the juice drink and baby sugar kelp was significantly lower than for all other foods ($p < .001$). Expected liking for the sushi was significantly higher than for all other foods ($p < .001$), and significantly lower for the juice drink ($p < .001$). See **Supplementary Table A.6.** for all other comparisons between individual foods.

[Insert **Table 3** about here]

4.4. Identifying drivers of acceptability for hypothetical seaweed-based food products

4.4.1. Construct validity and reliability of latent variables

Table 4 displays results for step 1 of the model testing latent variables. Where appropriate, scale items with standardised factor loadings < .50 were removed from the analysis for latent constructs; FTNS (4 items), Health interest (1 item), environmental impact (2 items), benefits of meat (1 item). For the BIDR-16 scale, 2 items with factor loadings < .50 were not removed, as doing so decreased reliability for the measure. Cronbach's alpha, McDonald's omega, and composite reliability values were > .70 for all measures, indicating adequate reliability across constructs.

Supporting convergent validity, AVE was > .50 for benefits of meat, environmental impact of foods, convenience orientation, and consumer acceptance. AVE was lower for desirable responding, health interest for foods, food neophobia, and food technology neophobia. However, discriminant validity of all constructs was supported, as the SQRT of the AVE along the diagonal was higher than the covariances for each corresponding pair (satisfying the Fornell-Larcker criterion). Heterotrait-monotrait (HTMT) ratios were acceptable across comparisons, as all values were < .85 (Henseler et al., 2014).

[Insert **Table 4** about here]

4.4.2. Direct and indirect effects on consumer acceptance

In step 2 of the analysis, the full structural model was approaching acceptable fit across indices overall (CFI = .810, RMSEA = 0.060, X^2 = 4503.28, df = 1677, p < .001), and accounted for 84.7% (R^2 = 0.847) of the variance in consumer acceptance. As shown in **Table 5**, having greater food neophobia and stronger beliefs about the benefits of meat significantly predicted decreased acceptance for hypothetical seaweed-based food products, whereas perceiving foods to be more tasty/ edible and familiar significantly predicted increased acceptance. Of these significant predictors, taste/ edibility appeared to have the largest influence on consumer acceptance. All other consumer traits and product beliefs were comparatively poor predictors of acceptability, and direct paths failed to reach significance.

When exploring indirect paths predicting consumer acceptance, the model showed that each consumer trait significantly predicted at least one product belief. However, food

neophobia was the only trait to have significant indirect effects on consumer acceptance via both taste/ edibility and familiarity, indicating partial mediation (given the significant direct effect of food neophobia on consumer acceptance). For all other indirect effects containing taste/ edibility and familiarity, $p > .05$ and/ or confidence intervals crossed zero (see **Table 6**).

To explore the development of a more parsimonious model of consumer acceptance, product beliefs that did not significantly predict consumer acceptance, and consumer traits that did not significantly predict consumer acceptance via direct or indirect paths, were removed from the model. This meant that food neophobia and beliefs about the benefits of meat were included as antecedent predictors of acceptance, and taste/ edibility and familiarity were included as intervening endogenous constructs.

Though model trimming alone appeared to have little influence on the model fit (CFI = .872, RMSEA = 0.099, $X^2 = 1028.91$, df = 182, $p < .001$), this noticeably improved when covariances between items within the FNS and benefits of meat were accounted for after checking modification indices (CFI = .953, RMSEA = 0.063, $X^2 = 472.36$, df = 162, $p < .001$). Consistent with the full model, the revised model explained 83.9% ($R^2 = 0.839$) of the variance in consumer acceptance. Direct paths predicting consumer acceptance remained significant for food neophobia ($\beta = -0.20$, $p < .001$, 95% CI = -5.64 – -2.98), benefits of meat ($\beta = -0.10$, $p < .001$, 95% CI = -3.24 – -0.97), taste/ edibility ($\beta = 0.76$, $p < .001$, 95% CI = 0.58 – 0.76), and familiarity ($\beta = 0.05$, $p = .025$, 95% CI = 0.00 – .09). Indirect effects of food neophobia on consumer acceptance via taste/ edibility ($\beta = -0.35$, $p < .001$, 95% CI = -9.26 – -5.79) and familiarity ($\beta = -0.01$, $p = .038$, 95% CI = -0.62 – -0.02) also remained significant. There was no significant indirect effect of beliefs about the benefits of meat on consumer acceptance via familiarity ($\beta = 0.00$, $p = .153$, 95% CI = -0.29 – 0.00), but contrasting with the full model, the indirect effect via taste/ edibility was significant (β = -

0.16, $p < .001$, 95% CI = -4.61 – -1.67). For this reason, the full model was accepted as a more conservative 'final' fit.

[Insert **Table 5** about here]

[Insert **Table 6** about here]

5. Discussion

This online study aimed to further explore the consumer acceptability of seaweed-based food products in the UK, and help identify specific drivers of acceptance for seaweeds. First and foremost, it was predicted that positive perceptions of seaweed-based food products (including seaweed as a complimentary ingredient) would be significantly related to consumer acceptance for seaweed-based food products. In this study, taste/ edibility and familiarity were the only product attributes to significantly predict acceptability, and taste/ edibility in particular was identified as the stronger driver of consumer acceptance. Previous research has shown that willingness to try is lower when consumers generally perceive seaweeds to be less tasty and appealing (Palmieri & Forleo, 2020; Wendin & Undeland, 2020), and that consumers are more likely to eat seaweeds when they are familiar with its use as an ingredient in dishes such as sushi (Birch et al., 2019). Our study extends these results to specific examples of potential seaweed-based food products, and further delineates the importance of taste/ edibility and familiarity for acceptance of seaweeds from the influence of

448 other product-related attributes, such as health and sustainability (Birch et al., 2019; Losada-
449 Lopez et al., 2021; Palmieri & Forleo, 2020; Wendin & Undeland, 2020).

450 Second, it was predicted that hypothetical seaweed-based food products would be
451 perceived more favourably than a general description of edible seaweeds, as this has been
452 recognised as a method to improve the palatability of seaweeds for Western consumers
453 (Birch et al., 2019; Chapman et al., 2015). In support of this, we found some evidence that
454 hypothetical seaweed-based products were rated more favourably in terms of taste/ edibility
455 (4 of 6 products), as well as familiarity (2 of 6 products). Given that both attributes were
456 identified as strong predictors of acceptance across models, results further emphasise the
457 importance of exploring consumer perceptions of seaweeds in a product-focussed context.
458 Indeed, this study has particular implications for guiding future product development, as
459 results highlight potential food products that may successfully incorporate seaweeds to
460 enhance acceptance for UK consumers.

461 Importantly, by contrasting a range of hypothetical food products, this study helps
462 identify differences in acceptability between potential food items. Overall, participants were
463 most accepting of the seaweed-based sushi and burger, and least accepting of the juice drink
464 and baby sugar kelp. Similar findings have been reported in past research, as consumers
465 favourably rate seaweeds when framed for use in main dishes, and often give lower ratings
466 for seaweeds when presented in sweet foods and beverages (Chapman et al., 2015; Wendin &
467 Undeland, 2020). One explanation for this is that consumers, particularly in the UK, are most
468 likely to be familiar with use of seaweeds in savoury items. Sushi, soups, and snacks (e.g.,
469 crackers) are the most common seaweed-based food products currently available in UK
470 supermarkets (Bouga & Combet, 2015), and traditional recipes in the UK often make use of
471 seaweeds as a main dish (e.g., ‘laverbread’) (Adams, 2016; Mahadevan, 2015). More
472 generally, meat-free burger patties are also a common example of products incorporating

alternatives to animal-based proteins that are widely available to consumers, such as plant-based and mycoprotein options (Onwezen et al., 2021). However, there is some evidence that seaweeds can be successfully introduced into other products, as 'chocolate ice cream with sugar kelp' was the highest rated item in one of the few studies where participants actually consumed real foods (Chapman et al., 2015). This suggests that, for less familiar (or expected) product contexts, allowing consumers the opportunity to taste products could help improve acceptability.

It is generally well-documented that acceptance for alternatives to animal-based proteins differs between consumers (Onwezen et al., 2021). For seaweeds in particular, previous studies have highlighted food neophobia as a crucial barrier to consumer acceptance (Birch et al., 2019; Losada-Lopez et al., 2021; Palmieri & Forleo, 2020). Though it should be acknowledged that the FNS may not be the most appropriate measure of food neophobia in other populations and food contexts (Damsbo-Svendsen et al., 2017), food neophobia (in conjunction with beliefs about the benefits of meat) was one of the only traits to significantly predict acceptability in this study. This further differentiates effects from the influence of other food-related attitudes that are typically investigated within this domain (e.g. global beliefs about the environmental impact of food, health interest, and convenience orientation for food). However, we also found evidence that the effect of food neophobia in particular was partially mediated by beliefs about the taste/ edibility and familiarity of products, suggesting that these attributes may potentially mitigate the negative effect of food neophobia on consumer acceptance. Palmieri and Forleo (Palmieri & Forleo, 2020) found similar effects in Italian consumers, reporting that perceptions of seaweed attributes and the option to taste-test a product could improve acceptability in neophobic consumers. Though familiarity had a relatively small effect compared to taste/ edibility, these findings highlight the perception of

both taste/ edibility and familiarity as specific factors that may combat potential barriers to consumer acceptance for seaweeds.

Measuring consumer acceptance in response to food descriptions can be particularly useful to identify initial interest in novel products (as developing and testing *real* food items can be costly in terms of time and resources). However, one concern with this approach is that information provided to consumers can prime responding. In this study, contrasting with our prediction that hypothetical seaweed-based food products would be rated more positively across dimensions, the general description of seaweeds as a food source was perceived to be healthier, less calorific, more natural, less processed, and less expensive than hypothetical seaweed-based food products. This was likely (at least in part) influenced by the nutritional information provided to participants in the food description (e.g., they were specifically informed that seaweeds are low-energy and high in vitamins and minerals, and presented with examples of 'natural' seaweeds). Indeed, there was some evidence that a ceiling effect may have occurred for beliefs about healthiness, naturalness, expensiveness, and sustainability/ ethics, as the 25th percentile for ratings of seaweed-based food products was ≥ 59 (above the midpoint of the scale), indicating a potential bias towards higher ratings. We do note that responses still varied among participants, with few selecting maximum scale scores (≤ 1.3% for each variable). Nevertheless, it remains unclear whether participants' beliefs accurately reflect their current knowledge and experience of consuming seaweeds as a food source, and future qualitative research on the consumer understanding of edible seaweeds would be beneficial.

As previously suggested, there remains a need to further explore consumer acceptance in response to taste-tests for seaweeds. This is particularly important given that some research has shown that participants often overestimated their expected liking (and acceptance) for similar products (foods containing the microalgae 'spirulina'), and actual liking of foods led

to participants feeling disappointed (Grahl et al., 2020). There is also some evidence to suggest that acceptance for seaweeds may be lower than for other products available to consumers, and further research is needed to compare acceptance for seaweed-based foods with other products. For example, compared to fish and other seafoods, US consumers gave lower average liking scores to seaweeds (Labbe et al., 2019), and were often willing to pay less of a price premium for products (Brayden et al., 2018). In a study on consumers in the Netherlands, only 12% of participants selected a product made from seaweed as their preferred choice for a hypothetical snack, compared to 54% who selected a hybrid meat/ meat substitute, and 30% who selected a snack made from lentils or beans (de Boer et al., 2013). In such studies, it would be useful to further explore *why* consumers would choose one alternative over another (Onwezen et al., 2021).

It should be noted that additional challenges in the development of seaweed-based food products have been identified in the literature, particularly as this relates to intensity/ volume of consumption. First, one potential concern is that frequently consuming seaweeds in large amounts may increase dietary intake above recommended levels for some micronutrients (e.g., iodine), and some species/ cultivation environments may be associated with increased toxicity (Cherry et al., 2019; Circuncisão et al., 2018). Regulations to guide seaweed farming and product development require greater clarity in several countries, including the UK (Bouga & Combet, 2015; Cherry et al., 2019; Circuncisão et al., 2018). Second, it may be difficult to produce high-protein foods using seaweeds alone given that reports of protein content widely vary across species (Cherry et al., 2019; Circuncisão et al., 2018; Fleurence et al., 2012), and large quantities may be less acceptable to consumers (Grahl et al., 2020; Lamont & McSweeney, 2021). However, use of seaweeds as an additional ingredient within other foods (as described in hypothetical contexts used in this

546 study) that may fortify nutritional qualities – such as protein content – remains a promising
547 avenue to explore (e.g., (Bouga & Combet, 2015)).

548 Limitations of the sample should also be addressed. First, this sample predominantly
549 included participants who self-identified as meat and/ or fish consumers, and few participants
550 reported following a vegan or vegetarian diet (7%). Though we found little evidence of an
551 effect of the consumers' diet on acceptance in supplementary analyses (see **Tables A.3 – 4**),
552 the role of the consumers' current diet in predicting acceptance for seaweed-based food
553 products may have been underestimated in this sample, and future research should consider
554 whether there are specific between-group differences. For instance, it has previously been
555 reported that consumers with a preference for meat, and vegetarians/ vegans, differ in their
556 likelihood of eating seaweeds in the future (Birch et al., 2019), as well as their beliefs about
557 meat and alternatives to animal-based proteins more generally in terms of taste, texture, price,
558 ease of preparation, nutritional content, and environmental benefits (Michel et al., 2021).
559 Second, the majority of participants were well-educated, with 60% of participants having
560 completed education at a university-level, and a further 12% reporting being current students.
561 As previous research has suggested that higher education levels can increase acceptability for
562 seaweeds and other alternatives to animal-based proteins (Birch et al., 2019; de Boer et al.,
563 2013; Palmieri & Forleo, 2020), the generalisability of results should be treated with caution,
564 and greater interest may be given to the role of education level in future work as a key
565 consumer demographic.

566

567 **6. Conclusions**

568

To the best of our knowledge, this is one of the first studies to directly explore the consumer acceptability of seaweed-based food products in the UK. Results indicate that consumers perceived hypothetical seaweed-based products to be tastier/ more edible than a general description of seaweeds as a food source. Taste/ edibility and familiarity were highlighted as strong drivers of acceptability, with taste/ edibility in particular identified as an attribute that could further enhance acceptance in consumers, and potentially mitigate the effects of food neophobia as a barrier to acceptance. Results suggest that consumers in the UK are accepting of seaweeds, and this study identifies scope for future research to further explore product development strategies for seaweed-based foods.

7. Acknowledgements

We gratefully acknowledge the in-kind contribution of consultancy from Dr Louise Neilson, BIC Innovation.

8. CRediT authorship contribution statement:

Rochelle Embling: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing – review and editing, Funding acquisition. **Louise Neilson:** Conceptualization, Methodology, Writing – review and editing, Funding acquisition. **Tennessee Randall:** Formal analysis, Writing – review and editing. **Chloe Mellor:** Methodology, Writing – review and editing. **Michelle D. Lee:** Conceptualization, Writing – review and editing, Funding acquisition. **Laura L. Wilkinson:** Conceptualization,

Methodology, Writing - original draft, Writing – review and editing, Supervision, Project administration, Funding acquisition.

9. Funding

This work was supported by the Economic and Social Research Council [grant number ES/V502200/1: ESRC IAA/DTP NPIF ABC]. RE also receives funding from the ESRC Wales Doctoral Training Partnership, Project Reference: ES/P00069X/1, Studentship 197139.

References

Adams, J. (2016). An overview on seaweed uses in the UK: Past, present and future. *Seaweed Resources*, *36*, 16–21.

Birch, D., Skallerud, K., & Paul, N. A. (2019). Who are the future seaweed consumers in a Western society? Insights from Australia. *British Food Journal*, *121*(2), 603–615. https://doi.org/10.1108/BFJ-03-2018-0189

Bouga, M., & Combet, E. (2015). Emergence of seaweed and seaweed-containing foods in the uk: Focus on labeling, iodine content, toxicity and nutrition. *Foods*, *4*(2), 240–253. https://doi.org/10.3390/foods4020240

Brayden, W. C., Noblet, C. L., Evans, K. S., & Rickard, L. (2018). Consumer preferences for seafood attributes of wild-harvested and farm-raised products. *Aquaculture Economics and Management*, *22*(3), 362–382. https://doi.org/10.1080/13657305.2018.1449270

Candel, M. J. J. M. (2001). Consumers' convenience orientation towards meal preparation: Conceptualization and measurement. *Appetite*, *36*(1), 15–28. https://doi.org/10.1006/appe.2000.0364

Chapman, A. S., Stévant, P., & Larssen, W. E. (2015). Food or fad? Challenges and opportunities for including seaweeds in a Nordic diet. *Botanica Marina*, *58*(6), 423–433. https://doi.org/10.1515/bot-2015-0044

Cherry, P., O'hara, C., Magee, P. J., Mcsorley, E. M., & Allsopp, P. J. (2019). Risks and benefits of consuming edible seaweeds. In *Nutrition Reviews* (Vol. 77, Issue 5, pp. 307–329). Oxford University Press. https://doi.org/10.1093/nutrit/nuy066

Circuncisão, A. R., Catarino, M. D., Cardoso, S. M., & Silva, A. M. S. (2018). Minerals from macroalgae origin: Health benefits and risks for consumers. In *Marine Drugs* (Vol. 16, Issue 11, p. 400). MDPI AG. https://doi.org/10.3390/md16110400

Cox, D. N., & Evans, G. (2008). Construction and validation of a psychometric scale to measure consumers' fears of novel food technologies: The food technology neophobia scale. *Food Quality and Preference*, *19*(8), 704–710. https://doi.org/10.1016/j.foodqual.2008.04.005

630 Damsbo-Svendsen, M., Frøst, M. B., & Olsen, A. (2017). A review of instruments developed
631 to measure food neophobia. *Appetite*, *113*, 358–367.
632 https://doi.org/10.1016/J.APPET.2017.02.032

633 de Boer, J., Schösler, H., & Boersema, J. J. (2013). Motivational differences in food
634 orientation and the choice of snacks made from lentils, locusts, seaweed or '"hybrid"'
635 meat. *Food Quality and Preference*, *28*, 32–35.
636 https://doi.org/10.1016/j.foodqual.2012.07.008

637 Elzerman, J. E., Hoek, A. C., van Boekel, M. A. J. S., & Luning, P. A. (2011). Consumer
638 acceptance and appropriateness of meat substitutes in a meal context. *Food Quality and*
639 *Preference*, *22*(3), 233–240.
640 https://doi.org/https://doi.org/10.1016/j.foodqual.2010.10.006

641 Elzerman, J. E., Hoek, A. C., van Boekel, M. J. A. S., & Luning, P. A. (2015).
642 Appropriateness, acceptance and sensory preferences based on visual information: A
643 web-based survey on meat substitutes in a meal context. *Food Quality and Preference*,
644 *42*, 56–65. https://doi.org/https://doi.org/10.1016/j.foodqual.2015.01.010

645 Fleurence, J., Morançais, M., Dumay, J., Decottignies, P., Turpin, V., Munier, M., Garcia-
646 Bueno, N., & Jaouen, P. (2012). What are the prospects for using seaweed in human
647 nutrition and for marine animals raised through aquaculture? *Trends in Food Science*
648 *and Technology*, *27*(1), 57–61. https://doi.org/10.1016/j.tifs.2012.03.004

649 Fritz, M. S., & MacKinnon, D. P. (2007). Required sample size to detect the mediated effect.
650 *Psychological Science*, *18*(3), 233–239. https://doi.org/10.1111/j.1467-
651 9280.2007.01882.x

652 Godfray, H. C. J., Aveyard, P., Garnett, T., Hall, J. W., Key, T. J., Lorimer, J., Pierrehumbert,
653 R. T., Scarborough, P., Springmann, M., & Jebb, S. A. (2018). Meat consumption,
654 health, and the environment. *Science*, *361*(6399), eaam5324.
655 https://doi.org/10.1126/science.aam5324

656 Gómez-Luciano, C. A., de Aguiar, L. K., Vriesekoop, F., & Urbano, B. (2019). Consumers'
657 willingness to purchase three alternatives to meat proteins in the United Kingdom,
658 Spain, Brazil and the Dominican Republic. *Food Quality and Preference*, *78*.
659 https://doi.org/10.1016/j.foodqual.2019.103732

660 Grahl, S., Strack, M., Mensching, A., & Mörlein, D. (2020). Alternative protein sources in
661 Western diets: Food product development and consumer acceptance of spirulina-filled
662 pasta. *Food Quality and Preference*, *84*, 103933.
663 https://doi.org/10.1016/j.foodqual.2020.103933

664 Grahl, S., Strack, M., Weinrich, R., & Mörlein, D. (2018). Consumer-Oriented Product
665 Development: The Conceptualization of Novel Food Products Based on Spirulina
666 (*Arthrospira platensis*) and Resulting Consumer Expectations. *Journal of Food Quality*,
667 *2018*, 1919482. https://doi.org/10.1155/2018/1919482

668 Hair, J., Babin, B., & Krey, N. (2017). Covariance-Based Structural Equation Modeling in
669 the Journal of Advertising: Review and Recommendations. *Journal of Advertising*,
670 *46*(1), 163–177. https://rdw.rowan.edu/business_facpub

671 Hair, J., Sarstedt, M., Hopkins, L., & Kuppelwieser, V. G. (2014). Partial least squares
672 structural equation modeling (PLS-SEM): An emerging tool in business research.
673 *European Business Review*, *26*(2), 106–121. https://doi.org/10.1108/EBR-10-2013-0128

674 Hart, C. M., Ritchie, T. D., Hepper, E. G., & Gebauer, J. E. (2015). The Balanced Inventory
675 of Desirable Responding Short Form (BIDR-16). *SAGE Open*, *5*(4).
676 https://doi.org/10.1177/2158244015621113

677 Henseler, J., Ringle, C. M., & Sarstedt, M. (2014). A new criterion for assessing discriminant
678 validity in variance-based structural equation modeling. *Journal of the Academy of*
679 *Marketing Science 2014 43:1*, *43*(1), 115–135. https://doi.org/10.1007/S11747-014-
680 0403-8

681 Koning, W. de, Dean, D., Vriesekoop, F., Aguiar, L. K., Anderson, M., Mongondry, P.,
682 Oppong-Gyamfi, M., Urbano, B., Luciano, C. A. G., Jiang, B., Hao, W., Eastwick, E.,
683 Jiang, Z. (Virgil), & Boereboom, A. (2020). Drivers and Inhibitors in the Acceptance of
684 Meat Alternatives: The Case of Plant and Insect-Based Proteins. *Foods 2020, Vol. 9,*
685 *Page 1292*, *9*(9), 1292. https://doi.org/10.3390/FOODS9091292

686 Labbe, R., Bernier, R., Mccray, N., Bouchard, D., Camire, M. E., Davis, C. V, Shaler, G., &
687 Dumont, R. (2019). *Consumer Attitudes and Preferences about Farm-Raised Shellfish,*
688 *Finfish, and Sea Vegetables in the Atlantic Coast States*.
689 https://www.texasaquaculture.org/PDF/2019 PDF Documents/Consumer Attitudes -

690 Aquaculture Product.pdf

691 Lamont, T., & McSweeney, M. (2021). Consumer acceptability and chemical composition of
692 whole-wheat breads incorporated with brown seaweed (Ascophyllum nodosum) or red
693 seaweed (Chondrus crispus). *Journal of the Science of Food and Agriculture*, *101*(4),
694 1507–1514. https://doi.org/10.1002/jsfa.10765

695 Lang, M. (2020). Consumer acceptance of blending plant-based ingredients into traditional
696 meat-based foods: Evidence from the meat-mushroom blend. *Food Quality and*
697 *Preference*, *79*, 103758. https://doi.org/10.1016/J.FOODQUAL.2019.103758

698 Losada-Lopez, C., Dopico, D. C., & Faína-Medín, J. A. (2021). Neophobia and seaweed
699 consumption: Effects on consumer attitude and willingness to consume seaweed.
700 *International Journal of Gastronomy and Food Science*, *24*, 100338.
701 https://doi.org/10.1016/j.ijgfs.2021.100338

702 Mahadevan, K. (2015). Seaweeds: a sustainable food source. In B. K. Tiwari & D. Troy
703 (Eds.), *Seaweed sustainability: Food and non-food applications* (pp. 347–364). Elsevier
704 Science & Technology.

705 Michel, F., Hartmann, C., & Siegrist, M. (2021). Consumers' associations, perceptions and
706 acceptance of meat and plant-based meat alternatives. *Food Quality and Preference*, *87*,
707 104063. https://doi.org/10.1016/j.foodqual.2020.104063

708 Mozaffarian, D., & Ludwig, D. S. (2010). Dietary Guidelines in the 21st Century-a Time for
709 Food. *JAMA*, *304*(6), 681–682.

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

714 Palmieri, N., & Forleo, M. B. (2020). The potential of edible seaweed within the western diet.
715 A segmentation of Italian consumers. *International Journal of Gastronomy and Food*
716 *Science*, *20*, 100202. https://doi.org/10.1016/j.ijgfs.2020.100202

717 Palmieri, N., & Forleo, M. B. (2021). An Explorative Study of Key Factors Driving Italian
718 Consumers' Willingness to Eat Edible Seaweed. *Journal of International Food and*

719 *Agribusiness Marketing*. https://doi.org/10.1080/08974438.2021.1904082

720 Pliner, P., & Hobden, K. (1992). Development of a scale to measure the trait of food
721 neophobia in humans. *Appetite*, *19*(2), 105–120. https://doi.org/10.1016/0195-
722 6663(92)90014-W

723 Possidónio, C., Prada, M., Graça, J., & Piazza, J. (2021). Consumer perceptions of
724 conventional and alternative protein sources: A mixed-methods approach with meal and
725 product framing. *Appetite*, *156*, 104860. https://doi.org/10.1016/j.appet.2020.104860

726 Roininen, K., Lähteenmäki, L., & Tuorila, H. (1999). Quantification of consumer attitudes to
727 health and hedonic characteristics of foods. *Appetite*, *33*(1), 71–88.
728 https://doi.org/10.1006/appe.1999.0232

729 Rosseel, Y. (2012). lavaan: An R Package for Structural Equation Modeling. *Journal of*
730 *Statistical Software*, *48*(2), 1–36. https://doi.org/10.18637/JSS.V048.I02

731 Rust, N. A., Ridding, L., Ward, C., Clark, B., Kehoe, L., Dora, M., Whittingham, M. J.,
732 McGowan, P., Chaudhary, A., Reynolds, C. J., Trivedy, C., & West, N. (2020). How to
733 transition to reduced-meat diets that benefit people and the planet. *Science of the Total*
734 *Environment*, *718*, 137208. https://doi.org/10.1016/j.scitotenv.2020.137208

735 Stoll-Kleemann, S., & O'Riordan, T. (2015). The sustainability challenges of our meat and
736 dairy diets. *Environment*, *57*(3), 34–48. https://doi.org/10.1080/00139157.2015.1025644

737 Verbeke, W. (2015). Profiling consumers who are ready to adopt insects as a meat substitute
738 in a Western society. *Food Quality and Preference*, *39*, 147–155.
739 https://doi.org/10.1016/j.foodqual.2014.07.008

740 Wendin, K., & Undeland, I. (2020). Seaweed as food – Attitudes and preferences among
741 Swedish consumers. A pilot study. *International Journal of Gastronomy and Food*
742 *Science*, *22*, 100265. https://doi.org/10.1016/j.ijgfs.2020.100265

743

744 **Table 1.** Descriptions of ‘seaweed’ and ‘seaweed-based’ food products provided to
745 participants.

Product	Description
Algae/ seaweeds	"Algae" are a type of low-energy aquatic plant that has been found to be high in protein, vitamins, minerals, fibre, and fatty acid. There are many types of algae that can be included in food products. This includes 'laver', 'kelp', ‘wakame’, ‘ogo’, ‘sea grapes', and ‘mozuku’. A more common name for algae is ‘seaweeds’.
Energy bar	A "Kelp and nut energy bar" is a protein-rich food product that contains kelp (a type of algae or seaweed). It also contains ingredients like oats, mixed nuts, and dried fruits.
Burger	A "Seaweed burger" is a protein-rich food product that contains seaweed (or algae). It is a meat-free patty, and can also contain ingredients like soy.
Pasta	"Kelp noodles" is a protein-rich food product that contains kelp (a type of algae or seaweed). As it is typically made with only seaweed-derived substances and water, it is also low in calories and high in vitamins and minerals.
Sushi	"Wakame sushi rolls" is a protein-rich food product that contains nori and wakame (types of algae or seaweed). Nori is used as a wrap, and wakame is used in a filling that also contains sushi rice and vegetables.
Juice drink	"Seaweed juice drink" is a protein-rich beverage that contains seaweeds (or algae). These drinks are typically high in vitamins and minerals, and also often contain additional fruits, vegetables, and flavourings.
Baby sugar kelp	"Baby sugar kelp" is a type of algae or seaweed that is harvested when it is small. It is high in vitamins and minerals, retains its sweetness and is not too salty. You can use it as a garnish, or as an ingredient in desserts.

746

747 **Table 2.** Sample characteristics (N = 476)

Consumer trait	Range	M (SD)
Age (years)	18.0 – 76.0	37.1 (13.7)
BMI (kg/m^2)	14.9 – 55.3	25.7 (5.8)
Food neophobia (FNS) [1]	10 – 47	23.8 (7.1)
Food technology neophobia (FTNS) [1]	20 – 82	49.4 (10.9)
Health interest for foods [2]	1.4 – 6.9	4.2 (1.0)
Convenience orientation (CONVOR-scale) [1]	6 – 42	24.1 (8.1)
Environmental impact of food [1]	7 – 25	18.6 (3.4)
Benefits of meat [1]	6 – 30	19.2 (6.2)
Desirable responding (BIDR-16) [2]	1 – 7	4.3 (1.0)

748 [1] Sum of item scores in scale.

749 [2] Mean scale score calculated across items.

750

751 **Table 3.** Descriptive statistics for beliefs about foods and consumer acceptance ratings, measured using 100-mm VAS. Mean (SD) is reported.

Variable	Algae/ seaweeds	Energy bar	Burger	Pasta	Sushi	Juice drink	Baby sugar kelp	Across foods [1]
Product belief								
Taste/ edibility	52 (24)	63 (24)	61 (24)	66 (22)	75 (26)	47 (26)	51 (25)	61 (17)
Healthiness	82 (15)	75 (17)	71 (18)	82 (14)	78 (17)	80 (17)	73 (18)	77 (12)
Calories	29 (19)	58 (20)	49 (20)	28 (22)	43 (22)	42 (23)	34 (21)	42 (14)
Naturalness	86 (19)	69 (18)	64 (22)	73 (19)	73 (19)	73 (21)	82 (19)	72 (14)
Processing	27 (24)	51 (22)	57 (24)	47 (24)	43 (22)	47 (23)	26 (22)	45 (17)
Expensiveness	56 (20)	63 (17)	64 (15)	63 (19)	71 (17)	73 (17)	63 (22)	66 (13)
Ethics/ Sustainability	74 (18)	71 (16)	72 (16)	73 (17)	71 (17)	72 (17)	72 (19)	72 (14)
Familiarity	34 (27)	44 (28)	36 (29)	32 (26)	64 (28)	33 (27)	21 (23)	38 (19)
Acceptability								
Readiness to adopt	42 (32)	37 (33)	53 (35)	44 (33)	55 (36)	25 (30)	29 (30)	41 (26)
Willingness to try	76 (27)	75 (28)	73 (29)	79 (24)	78 (29)	63 (31)	68 (29)	73 (22)

Willingness to buy	62 (28)	59 (30)	57 (31)	64 (27)	68 (32)	45 (31)	50 (29)	57 (23)
Liking	49 (27)	57 (30)	53 (28)	60 (25)	68 (33)	39 (28)	48 (27)	54 (20)

752 [1] Collapsed across hypothetical seaweed-based food products by averaging scores for individual items (excluding the general description of
753 algae/ seaweeds).

754

755

Table 4. CFA standardised factor loadings, reliability, construct validity, and discriminant validity of latent variables. For each individual construct, SQRT of AVE is displayed along the diagonal in bold. For each pairwise comparison, the factor covariance and heterotrait-monotrait (HTMT) ratio of correlation is presented.

Construct	Factor loadings	Cronbach α	McDonald ω	CR	AVE	Factor covariances, HTMT ratio							
						1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Desirable responding (BIDR-16)	0.471 – 0.639 (8 items)	0.781	0.782	0.782	0.311	**0.558**							
2. Benefits of meat	0.657 – 0.928 (5 items)	0.905	0.908	0.905	0.661	-0.073, 0.111	**0.813**						
3. Environmental impact of foods	0.601 – 0.879 (3 items)	0.749	0.775	0.774	0.539	0.073, 0.106	-0.230, 0.307	**0.734**					
4. Convenience orientation	0.553 – 0.934 (6 items)	0.907	0.911	0.911	0.637	-0.225, 0.234	0.001, 0.072	-0.114, 0.142	**0.798**				

	(CONVOR-scale)													
5.	Health interest for foods	0.502 – 0.786 (7 items)	0.841	0.845	0.846	0.444	0.169, 0.215	-0.232, 0.218	0.263, 0.341	-0.190, 0.198	**0.666**			
6.	Food neophobia (FNS)	0.512 – 0.754 (10 items)	0.885	0.893	0.893	0.460	-0.034, 0.123	0.085, 0.157	-0.194, 0.212	0.271, 0.279	-0.211, 0.225	**0.678**		
7.	Food technology neophobia (FTNS)	0.519 – 0.781 (9 items)	0.880	0.881	0.880	0.453	< -.001, 0.112	0.111, 0.177	-0.167, 0.222	0.176, 0.197	-0.062, 0.131	0.378, 0.367	**0.673**	
8.	Consumer acceptance	0.594 – 0.928 (4 items)	0.885	0.904	0.905	0.709	0.089, 0.128	-0.307, 0.431	0.379, 0.429	-0.181, 0.200	0.283, 0.306	-0.567, 0.533	-0.326, 0.341	**0.842**

759

760

761 **Table 5.** Coefficients for all direct paths predicting consumer acceptance in the structural model.

Predictor	B	SE	β	95% LLCI, ULCI	z	p
Consumer traits						
Age (yrs)	0.05	0.03	0.04	-0.07, 0.26	1.90	0.058
Desirable responding (BIDR-16)	-0.31	0.53	-0.02	-23.26, 24.83	-0.58	0.560
Benefits of meat	-1.69	0.46	-0.09	-16.27, 25.39	-3.66	**< 0.001**
Environmental impact of foods	0.58	0.62	0.03	-50.96, 118.91	0.95	0.344
Convenience orientation (CONVOR-scale)	-0.39	0.28	-0.04	-7.07, 7.82	-1.40	0.161
Health interest for foods	0.17	0.39	0.01	-62.47, 13.35	0.44	0.662
Food neophobia (FNS)	-4.04	0.73	-0.19	-10.35, 16.09	-5.55	**< 0.001**
Food technology neophobia (FTNS)	0.09	0.36	0.01	-7.82, 8.36	0.25	0.807
Expected product attributes						
Taste/ edibility	0.66	0.05	0.75	0.54, 0.77	13.47	**< 0.001**
Familiarity	0.06	0.02	0.07	0.01, 0.10	2.93	**0.003**

Healthiness	0.04	0.03	0.03	-0.57, 0.55	1.34	0.182
Calories	-0.05	0.03	-0.04	-0.14, 0.06	-1.75	0.080
Naturalness	0.01	0.03	0.01	-0.58, 0.33	0.30	0.768
Processing	0.02	0.02	0.02	-0.06, 0.14	0.88	0.377
Expensiveness	0.02	0.03	0.02	-0.04, 0.08	0.91	0.362
Sustainability/ ethics	-0.02	0.03	-0.02	-0.34, 0.17	-0.70	0.483

762

763

764 **Table 6.** Coefficients for indirect paths predicting consumer acceptance.[1]

Consumer traits	Mediating variable	Indirect effect						Total effect					
		B	SE	95% LLCI, ULCI	β	z	p	B	SE	95% LLCI, ULCI	β	z	p
Age (yrs)	Taste/ edibility	-0.01	0.03	-0.08, 0.06	-0.01	-0.41	0.680	0.04	0.04	-0.10, 0.25	0.03	0.89	0.375
	Familiarity	-0.01	0.01	-0.03, 0.00	-0.01	-2.39	0.017	0.04	0.03	-0.08, 0.22	0.03	1.38	0.168
Desirable	Taste/ edibility	1.50	0.55	-1.73, 10.46	0.09	2.70	0.007	1.19	0.76	-23.30, 24.52	0.07	1.56	0.118
responding	Familiarity	-0.02	0.06	-0.27, 0.15	0.00	-0.27	0.786	-0.32	0.53	-21.16, 26.10	-0.02	-0.61	0.544
(BIDR-16)													
Benefits of	Taste/ edibility	-1.41	0.57	-14.66, 7.10	-0.08	-2.48	0.013	-3.10	0.76	-18.04, 34.14	-0.17	-4.08	< .001
meat	Familiarity	-0.06	0.06	-0.47, 0.09	0.00	-1.00	0.316	-1.75	0.47	-14.68, 28.42	-0.10	-3.75	< .001
Environmental	Taste/ edibility	4.29	0.84	-37.48, 35.25	0.20	5.10	< .001	4.87	1.04	-37.71, 162.46	0.23	4.69	< .001
impact of	Familiarity	0.15	0.09	-0.33, 1.41	0.01	1.64	0.101	0.74	0.62	-52.90, 110.14	0.03	1.19	0.234
foods													
Convenience	Taste/ edibility	0.69	0.34	-1.50, 2.79	0.06	2.00	0.046	0.30	0.44	-7.24, 7.08	0.03	0.67	0.503

orientation (CONVOR-scale)	Familiarity	-0.01	0.04	-0.10, 0.09	0.00	-0.16	0.874	-0.40	0.28	-7.04, 8.13	-0.04	-1.41	0.159
Health interest for foods	Taste/ edibility	0.69	0.50	-9.23, 17.74	0.05	1.38	0.168	0.86	0.64	-45.22, 19.84	0.06	1.34	0.181
	Familiarity	0.06	0.06	-0.19, 0.48	0.00	1.08	0.280	0.23	0.40	-57.45, 13.71	0.02	0.59	0.556
Food neophobia (FNS)	Taste/ edibility	-5.76	0.87	-15.74, -0.41	-0.27	-6.61	**< .001**	-9.80	1.23	-24.07, 9.73	-0.47	-7.96	< .001
	Familiarity	-0.24	0.11	-0.67, -0.05	-0.01	-2.19	**0.029**	-4.28	0.74	-10.45, 15.89	-0.20	-5.82	< .001
Food technology neophobia (FTNS)	Taste/ edibility	-1.45	0.44	-7.11, 2.53	-0.11	-3.31	< .001	-1.37	0.56	-11.00, 7.94	-0.11	-2.43	0.015
	Familiarity	-0.02	0.05	-0.19, 0.08	0.00	-0.49	0.628	0.07	0.36	-7.82, 8.19	0.01	0.18	0.856

765 [1] Indirect effects are indicated as significant (in bold) if $p < .05$, and 95% confidence intervals do not cross zero.

766

767

768 **Figure 1**. Adapted from (Lang, 2020), proposed structural equation model for the acceptance
769 of seaweed-based food products, with consumer traits and beliefs about product attributes as
770 predictors of acceptability in this study.

771 Highlights (85 characters per bullet point):

772 • UK consumers were accepting of hypothetical seaweed-based food products
773 • Taste/ edibility was a strong driver of acceptance for seaweed-based foods
774 • Food neophobia was identified as a barrier to acceptance for seaweed-based foods
775 • Other product attributes (e.g., cost) were relatively poor predictors of acceptance
776 • Taste/ edibility and familiarity partially mediated the negative effect of food neophobia
777 on consumer acceptance

778