



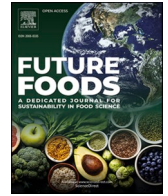
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Consumer knowledge and attitudes toward seaweed as food – a Swedish perspective

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ABSTRACT

Expanding seaweed production and consumption in Western societies may offer considerable socioeconomic benefits, addressing pressing health and sustainability challenges. To enhance understanding of attitudes, behaviors, and motivations related to seaweed food consumption, this study employed an observational cross-sectional online survey of 199 Swedish adults, focusing on knowledge and attitudes concerning health, environmental sustainability, and sensory aspects. The 31-item questionnaire included closed-ended, open-ended, and open-response-option questions, using check-all-that-apply and Likert-scales. Responses were analyzed through descriptive and inferential statistics, thematic analysis, and were discussed in relation to Theory of Planned Behavior and food-choice frameworks to identify key consumption determinants. Results showed that while over 95% of respondents expressed interest in seaweed, only 41% reported regular consumption, indicating an intention–behavior gap explained by perceived concerns and motivators. Concerns included potential contamination with heavy metals and iodine. Motivators for increased consumption encompassed appealing sensory attributes, availability, sustainability, nutrition, and quality. Participants requested increased visibility through media, in-store-promotion, and other awareness-building strategies. Seaweeds were recognized as sources of minerals, fiber, and high-quality protein, associated with saltiness, umami, and marine freshness. Some consumers preferred incorporating seaweed subtly into familiar foods (hiding), others valued showcasing its unique sensory qualities (highlighting). Although participants were mostly familiar with seaweeds through sushi and other elements of Southeast-Asian cuisines, many expressed positive attitudes toward integration into wider ranges of dishes, e.g., meat/fish substitutes or natural flavor-enhancers. Overall, this study explored seaweed acceptance across multiple levels of food choice, offering insights to guide product development, marketing, and sustainable production practices in Sweden and beyond.

1. Introduction

Increasing seaweed production and consumption in Western societies, such as in Sweden, holds potential for significant societal and economic benefits (European Commission, 2022; van den Burg et al., 2019). Seaweed (marine macroalgae) is widely recognized as a nutrient-dense, low-calorie food that is low in fat and rich in dietary fiber, micronutrients, and bioactive compounds (European Commission, 2022; Holdt and Kraan, 2011). Certain species also exhibit notably high

protein content, positioning seaweed as a promising contributor to the ongoing “protein shift”, which involves transforming dietary patterns away from meat- and dairy-based consumption toward plant-based and other sustainably sourced protein sources (van den Burg et al., 2019). However, establishing seaweed as an integral component of Western food cultures requires a deeper understanding of consumers’ attitudes and the factors influencing dietary behavior change, as these are reported to remain significant gaps in current knowledge (Blikra et al., 2021; European Commission, 2022; Sneath et al., 2023; The Swedish

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Board of Agriculture, 2024).

Previous research has examined consumer attitudes and behaviors toward seaweed as a food source across various segments and populations, including Australia and New Zealand (Birch et al., 2019a, 2019b; Rombach and Dean, 2024; Young et al., 2022), Nordic countries (Chapman et al., 2015; Gustavsen and Rautenberger, 2023; Wendin and Undeland, 2020), France (Lucas et al., 2019), Bangladesh (Sobuj et al., 2025), Italy (Palmieri and Forleo, 2020), UK (Embling et al., 2022; Govaerts and Olsen, 2024), North Americas (Moss and McSweeney, 2021; Zheng et al., 2024), Mexico (Tenorio-Rodríguez et al., 2025), and cross-national populations (Chen et al., 2024; Goecke et al., 2025; Laureati et al., 2024; Tomić Maksan et al., 2025). The current literature is scattered across different populations, and in the Swedish context, previously published research consists primarily of a pilot study by Wendin and Undeland (2020). Their study concluded that health, sustainability, and taste (sensory perception) serve as key drivers of increased seaweed consumption, while consumers' knowledge of seaweed and its culinary uses remain underexplored. Based on this, there is a need to provide an updated perspective on Swedish consumers' knowledge and attitudes that shape their intention to consume seaweed, as well as to explore barriers and motivators for greater consumption.

To better understand the determinants of seaweed consumption, this inductive study is guided by the Theory of Planned Behavior (Ajzen, 1985, 1991), which emphasizes attitudes, norms, and perceived behavioral control as predictors of food choice, in combination with established food choice frameworks (Fernqvist et al., 2024), which integrates various levels within the socioecological systems that shape consumers' food decisions.

According to Ajzen's Theory of Planned Behavior (Ajzen, 1985, 1991), human social behavior is described to unfold as a consequence of a series of more or less well-formulated plans. For instance, before eating a homemade meal, a person may have sourced recipes, gone grocery shopping, and cooked – activities that are often planned. Several factors influence an individual's intentions and subsequent behaviors. Previous literature on Western consumers' attitudes towards seaweed for food and their current consumption frequency indicates a gap between intention and behavior (Wendin and Undeland, 2020; Young et al., 2022). Whereas a large proportion of consumers have a positive attitude towards seaweed for food (>90%), few are eating it regularly today. This gap may stem from multiple factors that influence both consumers' intention to eat seaweed and their subsequent consumption behavior.

Factors influencing an individual's food choices can be understood through the socioecological model (Bronfenbrenner, 1977, 1979; Fernqvist et al., 2024). According to this model, determinants of food choice operate across four different levels: (I) food environment level, including availability, food characteristics (intrinsic, extrinsic, price), store environments, and promotion; (II) social/community level, including norms and culture; (III) interpersonal level (friends and family), and (IV) individual level. Thus, within these different levels, enablers for increased seaweed consumption can include greater accessibility, affordable price point, desirable packaging, and greater diversity of products (Young et al., 2022). Consumers' attitudes toward, and intentions of, eating seaweed are influenced by several factors across these levels, such as its uniqueness and naturalness (Govaerts and Ottar Olsen, 2023), as well as being perceived as environmentally sustainable, healthy/nutritious, with an attractive taste/flavor profile (van den Burg et al., 2019; Wendin and Undeland, 2020; Young et al., 2022). In addition, consumers with biospheric values (collectivistic motives such as concern for preserving the ecosystem and the biosphere as a whole) exhibited a higher likelihood of consuming seaweed (Govaerts and Ottar Olsen, 2023). Contrarily, food neophobia (Losada-Lopez et al., 2021) and sensory constraints (Dahlstedt et al., 2025) have been identified to obstruct greater consumption of seaweeds in Western diets.

In summary, this observational cross-sectional survey study aims to understand the role of seaweed in a future diet based on Swedish

consumers' (I) knowledge about seaweed, (II) knowledge of how to use seaweed, and (III) acceptance towards eating seaweed. Guided by the Theory of Planned Behavior and the socioecological model, the study situates these aspects within broader determinants of food choice, with a specific focus on health, environmental sustainability, and sensory perception.

2. Materials and methods

2.1. Study design

This cross-sectional exploratory survey study was based on a mixed-methods online questionnaire conducted remotely amongst Swedish adults between November 2024 and March 2025. The questionnaire was piloted via convenience sampling ($n = 4$) before deployment.

The final 31-item questionnaire started with demographic questions (Q1–5) which were followed by thematic sections, addressing health (Q6–8), sustainability (Q9–11), sensory aspects (Q12–16), and motivators (Q17–31) for seaweed consumption. Each section included questions on participants' knowledge of seaweed and its culinary uses, along with their acceptance of seaweed as food, in accordance with the study's aim. The questions are presented in Table 1–5 and Fig. 2.

The questionnaire consisted of a mix of closed-ended ($n = 6$; Q1–5, Q7), non-obligatory open-ended ($n = 2$; Q16, Q31), and open-response-option questions ($n = 9$; Q6, Q8–15) in check-all-that-apply (CATA) format, and seven-level Likert scale questions ($n = 14$; Q17–30). No time restriction was enforced on the survey, but a completion time of 10–15 min was estimated.

The questionnaire was developed and distributed via the Eye-Question software (version 6.0.9.3, Logic8 B.V., The Netherlands), which is widely used and designed for consumer studies.

2.2. Participants

Participants were recruited online through Kristianstad University's research study enrollment webpage, as well as via university homepages' news feeds, posters at public events, and social media platforms including LinkedIn, Instagram, and Facebook. The required sample size was determined using Cochran's formula for power calculation (Cochran, 1977), which is suitable for large populations. Assuming a 95% confidence level, a margin of error of 7% (normally between 1–10%), and a proportion estimate of 0.5, the minimum sample size representing the overall population was calculated to be 196 participants. This power calculation did not take subgroup comparisons into consideration. The inclusion criteria were an age of 18 years or older, current residence in Sweden, and completion of the entire survey.

A total of 292 participants responded to the survey. Among these, 199 participants met the inclusion criteria, whereas 93 participants were excluded due to not completing the survey ($n = 88$) or not residing in Sweden ($n = 5$). Hence, a questionnaire completion rate of 68.2% and a questionnaire completion time of 10.5 min were observed. No other data cleaning was conducted for the quantitative questionnaire items, as response patterns did not indicate a lack of participant engagement nor non-human responses.

Participants were segmented into subgroups based on their age: 18–29 years (Generation Z, 1996–2010), 30–44 years (Millennials, 1981–1995), 45–60 years (Generation X, 1965–1980), and 61–79+ years (Baby Boomers and older, –1964), as well as seaweed consumption frequency: consuming regularly and consuming rarely/never. The original consumption frequency categories (Q5) were collapsed to align with the conceptual distinction between active consumers and non-consumers. "Daily", "weekly", and "monthly" responses all represent intentional, repeated consumption, and thus were merged into a "regularly" category. "Less than once a month", "never", and "I don't know" were combined into a "rarely / never" group because they reflect low familiarity or minimal engagement with the product category.

Table 1
Demographics of the study participants ($n = 199$).

Participant characteristics	Frequency (n)	Percentage (%)
Q1: What is your age? (18 years or older as an inclusion criterion)		
18–29 (Generation Z, 1996–2010)	15	7.5
30–44 (Millennials, 1981–1995)	77	38.7
45–60 (Generation X, 1965–1980)	69	34.7
61–79+ (Baby Boomers and older, –1964)	38	19.1
		46.2
		53.8
Q2: In what country do you live? (Sweden as an inclusion criterion)		
Sweden	199	100
Other Nordic country	-	-
Other European country	-	-
Non-European country	-	-
Q3: Which gender do you identify as?		
Female	144	72.4
Male	53	26.6
Non-binary/other	1	0.5
Prefer not to say	1	0.5
Q4: Which category best describes your diet?		
Vegan	6	3.0
Lacto-ovo-vegetarian	13	6.5
Pescatarian	25	12.6
Omnivorous	153	76.9
Other	2	1.0
Q5: How often do you consume seaweed?		
Daily	3	1.5
Weekly	19	9.5
Monthly	60	30.2
Less than once a month	95	47.7
Never	15	7.5
I don't know	7	3.5
		41.2
		58.7

2.3. Data analysis

Quantitative data (Q1–15, Q17–30) were analyzed and reported as descriptive statistics, including means with standard deviations, medians, frequencies, and/or percentages in Microsoft Excel (version 2412, Microsoft Corp., USA). Statistical tests were selected based on the scale and distribution of the data and the study design. Significant differences between response options for the whole study sample (“All”) were assessed by pairwise comparison using Cochran’s Q test in IBM SPSS Statistics (version 29.0.0.0 (241), IBM, USA) for nominal CATA data (Q6–15) as described by [Delarue and Lawlor \(2022\)](#) and ANOVA with Tukey’s *post hoc* test in jamovi (version 2.6.44, The jamovi project, Australia) for ordinal Likert data (Q17–30). Differences between subgroups (“Age” and “Consumption frequency” in Q6–15) were evaluated based on estimated significance in paired comparisons as described by [Roessler et al. \(1978\)](#) by using the equation: $X = (z\sqrt{n} + n + 1)/2$, where X = minimum number of agreeing rp’s and n = number of trials, and z is set to 1.96 for $p \leq 0.05$. Normalised data, here percentage, was used in the pairwise comparison between subgroups.

Qualitative data (Q16, Q31) were analyzed through reflexive thematic analysis [Braun and Clarke \(2006\)](#) by manually identifying, analyzing, and reporting patterns (themes) within the dataset. Participants’ seaweed-based food suggestions (Q16) were illustrated using WordClouds (Zygomatic, The Netherlands). Before generating the word cloud, the textual data underwent preprocessing that included spelling correction, translation into English, removal of stop words, and harmonization of synonyms and grammatical variants. The themes generated from the participants’ self-reported motivators for increased seaweed consumption (Q31) were mapped onto the socioecological framework, illustrating different levels influencing food choice ([Bronfenbrenner, 1977, 1979; Fernqvist et al., 2024](#)).

2.4. Data quality

The survey was designed to embed and assess data quality *ex-ante* (before the event) and *post-hoc* (after the event) ([Jaeger and Cardello, 2022](#)). Initially, a definition of seaweed was presented to ensure the correctness of the respondents’ answers:

Table 2

Results from questions relating to seaweed and health. Age groups were categorized into Generation Z (15–29 years) and Millennials (30–44 years), as well as Generation X (45–60 years) and Baby Boomers (61 years and older). Seaweed consumption frequencies were categorized into regularly (daily, weekly, and monthly) and rarely (less than once a month, never, and I don't know). Results are given as a percentage (%) per group. Significant differences between answer options (Cochran's Q test; $p < 0.05$) are marked with lowercase letters, and pairwise comparisons between groups (Roessler et al. (1978), $p < 0.05$) are marked with italicized capital letters.

Question / Answer options	All (% of tot)	Age (% of age group)		Consumption frequency (% of frequency group)	
		Gen Z + Millennials	Gen X + Baby Boomers	Regularly	Rarely / Never
	(n = 199)	(n = 92)	(n = 107)	(n = 82)	(n = 117)
Q6: Which general constraints do you associate with seaweed? ^a					
Heavy metals	49.7 a	58.7 a	42.1 a	43.9 a	53.8 a
Toxic	15.1 c	19.6 bc	11.2 b	17.1 b	13.7 c
Dirt	9.5 cd	12.0 c	7.5 b	9.8 bc	9.4 c
Allergens	7.5 d	7.6 cd	7.5 b	9.8 bc	6.0 c
Spoilage / rotten	7.0 d	6.5 cd	7.5 b	2.4 cA	10.3 cB
Antinutrients	7.5 d	12.0 cA	3.7 bB	6.1 bc	8.5 c
Debris	6.0 d	9.8 cA	2.8 bB	8.5 bc	4.3 c
Not vegetarian (bycatch)	4.5 d	8.7 cA	0.9 cB	4.9 c	4.3 c
None of the above	31.7 b	25.0 b	37.4 a	36.6 a	28.2 b
Q7: Consider the food circle ^b – in what category would you place seaweed?					
Vegetables	72.9 a	72.8 a	72.9 a	79.3 a	68.4 a
Meat, fish, egg, legumes, nuts and seeds	13.6 b	12.0 b	15.0 b	9.8 b	16.2 b
Bread, cereals, grits, pasta and rice	3.5 c	1.1 c	5.6 c	0.0 c	6.0 c
Milk and cheese	0.0 cd	0.0 c	0.0 c	0.0 c	0.0 c
Potatoes and root crops	2.5 c	4.3 bc	0.9 c	1.2 c	3.4 c
Fruit and berries	0.5 c	0.0 c	0.9 c	1.2 c	0.0 c
Cooking fat	0.0 cd	0.0 c	0.0 c	0.0 c	0.0 c
None of the above	7.0 bc	9.8 bc	4.7 c	8.5 b	6.0 c
Q8: Which of the following claims would motivate you to eat seaweed the most?					
Good source of minerals	60.3 a	63.0 a	57.9 a	64.6 a	57.3 a
Good amino acid profile / good protein quality	41.2 b	48.9 b	34.6 b	46.3 b	37.6 b
High protein content	34.7 b	42.4 b	28.0 bc	36.6 bc	33.3 b
High fiber content	33.7 b	29.3 cd	37.4 b	29.3 c	36.8 bc
Low calory content	17.6 c	17.4 c	17.8 c	17.1 cd	17.9 c
Low carbohydrate content	11.6 cd	12.0 ce	11.2 cd	13.4 d	10.3 cd
High carbohydrate content	3.0 de	4.3 e	1.9 d	2.4 de	3.4 d
I would not like to eat seaweed	2.5 de	2.2 e	2.8 d	0.0 e	4.3 d
I don't know	9.0 d	6.5 ce	11.2 cd	6.1 de	11.1 cd

^aFree-text answers: other environmental toxins (n = 2), iodine (n = 9), pathogens/bacteria, microplastics, sea plants, low absorption of nutrients/protein.

^bFood circle: a Swedish dietary guideline model developed by the Swedish Food Agency (2025).

In this study, we define seaweed/algae products as products in which seaweed/algae is a prominent ingredient (such as in sushi, seaweed salt, seaweed burgers, etc.) and/or where seaweed/algae appear in the product name/description (such as seaweed caviar, seaweed roe, etc.). We use the term “seaweed” throughout the questionnaire.

Other measures for improved data quality included the choice of

Table 3

Results from questions relating to seaweed and environmental sustainability. Age groups were categorized into Generation Z (15–29 years) and Millennials (30–44 years), as well as Generation X (45–60 years) and Baby Boomers (> 61 years). Seaweed consumption frequencies were categorized into regularly (daily, weekly, and monthly) and rarely (less than once a month, never, and I don't know). Results are given as a percentage (%) per group. Significant differences between answer options (Cochran's Q test; $p < 0.05$) are marked with lowercase letters (a-h), and pairwise comparisons between groups (Roessler et al. (1978), $p < 0.05$) are marked with italicized capital letters (A-B).

Question / Answer options	All (% of tot)	Age (% of age group)		Consumption frequency (% of frequency group)	
		Gen Z + Millennials	Gen X + Baby Boomers	Regularly	Rarely / Never
	(n = 199)	(n = 92)	(n = 107)	(n = 82)	(n = 117)
Q9: Which of the following terms related to seaweed have you previously heard of? ^a					
Seaweed	93.5 a	92.4 ab	94.4 a	93.9 a	93.2 a
Algae	92.0 a	93.5 ab	90.7 a	90.2 ab	93.2 a
Nori	74.4 b	80.4 a	69.2 b	80.5 b	70.1 b
Kelp	68.8 b	77.2 c	61.7 bc	79.3 b	61.5 bc
Sea lettuce	59.3 c	51.1 de	66.4 b	62.2 d	57.3 c
Wakame	54.8 c	68.5 acdA	43.0 cdB	70.7 bcdA	43.6 dB
Sugar kelp	53.8 c	55.4 d	52.3 c	64.6 cdA	46.2 cdB
Kombu	30.7 d	37.0 f	25.2 de	48.8 defA	17.9 eB
Dulse	27.6 d	33.7 fA	22.4 deB	39.0 efA	19.7 eB
Ulva	25.1 d	37.0 fA	15.0 eB	36.6 fA	17.1 eB
Sea vegetables	24.6 d	17.4 gB	30.8 dA	36.6 fA	16.2 eB
Bacon of the sea	15.1 e	17.4 g	13.1 e	24.4 fgA	8.5 eB
None of the above	0.5 f	1.1 h	0.0 f	0.0 h	0.9 f
Q10: Do you think seaweed could be a part of the protein shift, and if so, how would you like to eat seaweed? ^b					
New protein-rich product	65.8 a	69.6 a	62.6 a	75.6 a	59.0 a
Flavor enhancer sauce or powder (to consume more legumes and vegetables)	57.8 ab	59.8 ab	56.1 a	63.4 ab	53.8 a
Protein-rich product based on whole seaweed pieces or powder	52.8 b	55.4 ab	50.5 a	52.4 b	53.0 a
Protein-rich product based on seaweed protein extract	40.2 bc	45.7 b	35.5 b	47.6 bc	35.0 b
I do not think that seaweed can be a part of this shift	3.5 d	2.2 c	4.7 c	0.0 d	6.0 c
None of the above	3.5 d	3.3 c	3.7 c	2.4 d	4.3 c
Q11: Which of the following claims are important for you to regard seaweed as a sustainable food choice? ^c					
Ecosystem friendly	75.4 a	79.3 a	72.0 a	78.0 a	73.5 a
Natural	52.8 b	52.2 bc	53.3 b	58.5 b	48.7 b
No herbicide use	51.8 b	53.3 bc	50.5 b	53.7 bc	50.4 b

(continued on next page)

Table 3 (continued)

Question / Answer options	All (% of tot) (n = 199)	Age (% of age group)		Consumption frequency (% of frequency group)	
		Gen Z + Millennials	Gen X + Baby Boomers	Regularly	Rarely / Never
		(n = 92)	(n = 107)	(n = 82)	(n = 117)
Locally sourced	50.8 b	55.4 b	46.7 b	57.3 b	46.2 b
No fertilizer use	46.2 b	44.6 bcd	47.7 b	48.8 bc	44.4 b
No or little land use	45.7 b	43.5 bcd	47.7 b	45.1 bc	46.2 b
No pesticide use	45.2 b	46.7 bcd	43.9 b	43.9 c	46.2 b
No or little freshwater use	40.7 bc	38.0 cd	43.0 b	40.2 c	41.0 bc
Carbon capture	35.2 c	44.6 bcdA	27.1 cB	40.2 c	31.6 c
Increased biodiversity	34.7 c	41.3 c	29.0 c	45.1 bcA	27.4 cdB
None of the above	0.5 d	0.0 e	0.9 d	0.0 d	0.9 e

a)Spirulina, Rörhinna (n = 2), Superfood of the sea (incorrect term), Bladderwrack (n = 2), Tare, Carrageenan, Agar.

b)New protein-rich product to replace fish, Replacement of part of meat in product, Unprocessed/salad (n = 8), In bread/smoothie (n = 3).

c)Sustainable harvesting methods, Meat-free with all its benefits.

software platform (EyeQuestion®, ISO 27,001/2022) used for online questionnaire administration, questionnaire length within normal ranges, inclusion of participants with varying questionnaire-taking experience, and high engagement with the topic, with intrinsic motivation to truthfully answer the questions. The question format was carefully altered to proactively further improve attention and engagement with the questionnaire. Nonetheless, participant engagement and non-human responses were inspected by studying response patterns. In addition, the software required respondents to complete all previous questionnaire items before they could proceed to the next. Finally, questionnaire completion rates as well as questionnaire completion times and item response times were assessed.

3. Results

3.1. Participant characteristics

Among the 199 participants included in the study, the average age was 48 ± 14 years (median 47 years), with a majority being women. Overall, 23.1% (n = 46) accommodated specific dietary preferences, and 41.2% (n = 82) consumed seaweed monthly or more often. All demographic characteristics are summarized in Table 1. Consumers who reported eating seaweed most frequently (daily to monthly) tended to be a younger segment (Generation Z and Millennials), female, and follow special diets such as vegan, lacto-ovo vegetarian, or flexitarian.

3.2. Health aspects

About a third of the participants (n = 63, 31.7%) did not associate any of the predefined constraints with seaweed (Table 2). Still, seaweed was associated with heavy metals (n = 99, 49.7%), and partly toxic (n = 30, 15.1%) and dirt (n = 19, 9.5%). The participants' own perceptions of food constraints related to seaweed included other environmental toxins (n = 2), iodine (n = 9), pathogens/bacteria, microplastics, sea plants, and low absorption of nutrients/protein. The consumer group that rarely eats seaweed was more concerned about spoiled and rotten material compared to the group that frequently consumes seaweed. Significant differences between age groups were observed regarding antinutrients, debris, and non-vegetarian bycatch. Generation Z and Millennials were more likely

Table 4

Results from questions relating to seaweed and sensory perception. Age groups were categorized into Generation Z (15–29 years) and Millennials (30–44 years), as well as Generation X (45–60 years) and Baby Boomers (> 61 years). Seaweed consumption frequencies were categorized into regularly (daily, weekly, and monthly) and rarely (less than once a month, never, and I don't know). Results are given as a percentage (%) per group. Significant differences between answer options (Cochran's Q test; p < 0.05) are marked with lowercase letters, and pairwise comparisons between groups (Roessler et al. (1978), p < 0.05) are marked with italicized capital letters.

Question / Answer options	All (% of tot) (n = 199)	Age (% of age group)		Consumption frequency (% of frequency group)	
		Gen Z + Millennials	Gen X + Baby Boomers	Regularly	Rarely / Never
		(n = 92)	(n = 107)	(n = 82)	(n = 117)
Q12: Which sensory perceptions do you associate with seaweed? ^a					
Saltiness	70.4 a	71.7 a	69.2 a	73.2 a	68.4 a
Fresh sea	63.3 ab	59.8 ab	66.4 a	69.5 a	59.0 ab
Umami	61.3 b	69.6 a	54.2 b	73.2 a	53.0 b
Chewy	46.7 c	47.8 b	45.8 b	51.2 b	43.6 bc
Grass / green	45.7 c	43.5 b	47.7 b	50.0 b	42.7 bc
Slimy	36.2 de	41.3 b	31.8 c	39.0 bc	34.2 c
Fish	33.2 e	42.4 bA	25.2 cdB	43.9 bcA	25.6 cdB
Seafood / shellfish	26.1 ef	27.2 c	25.2 cd	32.9 c	21.4 d
Vegetables	23.6 f	17.4 cde	29.0 c	29.3 cde	19.7 d
Spinach	17.6 fg	19.6 cd	15.9 d	19.5 cdef	16.2 de
Sweetness	13.1 fgh	17.4 cde	9.3 de	17.1 de	10.3 def
Boiled green vegetables	11.6 fghi	15.2 cde	8.4 de	17.1 de	7.7 e
Bitterness	9.5 fghi	13.0 def	6.5 de	12.2 def	7.7 e
Metallic / toxic	5.5 h	3.3 ef	7.5 de	7.3 def	4.3 ef
Sourness	4.0 hi	5.4 e	2.8 e	6.1 def	2.6 ef
Rotten	2.0 hij	1.1 ef	2.8 e	0.0 defg	3.4 ef
None of the above	1.5 hij	1.1 ef	1.9 e	1.2 defg	1.7 ef
Q13: In what food context would seaweed fit? ^b					
Savory side dish	82.9 a	83.7 a	82.2 a	90.2 a	77.8 a
Savory snack	71.9 b	79.3 ab	65.4 b	80.5 ab	65.8 a
Savory main dish	54.8 c	65.2 bA	45.8 cB	69.5 bA	44.4 bB
Sweet snack	19.6 d	19.6 c	19.6 d	30.5 cA	12.0 cB
Dessert	14.1 d	16.3 c	12.1 de	20.7 cA	9.4 cB
None of the above	1.5 e	1.1 d	1.9 e	1.2 d	1.7 c
Q14: In what cuisine could you accept to include seaweed? ^c					
South/east Asian	86.4 a	90.2 a	83.2 a	95.1 a	80.3 a
Nordic cuisine	69.3 b	68.5 b	70.1 b	73.2 b	66.7 b
Mediterranean	56.3 c	57.6 bc	55.1 c	62.2 b	52.1 c
Swedish traditional home cooked food (husmanskost)	42.2 d	48.9 c	36.4 d	46.3 c	39.3 d
French	29.1 e	33.7 d	25.2 de	39.0 cdA	22.2 eB
Indian	27.1 e	28.3 d	26.2 de	32.9 cd	23.1 e
Mexican	26.1 e	31.5 d	21.5 e	32.9 cd	21.4 e

(continued on next page)

Table 4 (continued)

Question / Answer options	All (% of tot)	Age (% of age group)		Consumption frequency (% of frequency group)	
		Gen Z + Millennials (n = 92)	Gen X + Baby Boomers (n = 107)	Regularly (n = 82)	Rarely / Never (n = 117)
Middle eastern	25.1 e	25.0 d	25.2 de	31.7 d	20.5 e
None of the above	0.5 f	0.0 e	0.9 f	0.0 e	0.9 f
Q15: In what form would you like to eat seaweed? ^d					
Roasted	57.8 a	63.0 a	53.3 a	64.6 a	53.0 a
Dried flakes	56.3 ab	60.9 ab	52.3 a	67.1 aA	48.7 abB
Dried sheets	55.8 ab	62.0 a	50.5 ab	64.6 aA	49.6 abB
Dried powder	51.8 ab	55.4 ab	48.6 ab	63.4 abA	43.6 abcB
Fresh	48.7 b	47.8 b	49.5 ab	61.0 abA	40.2 bB
Fermented	40.7 bc	34.8 bc	45.8 abcd	50.0 b	34.2 bc
Smoked	34.2 c	33.7 c	34.6 cd	40.2 bc	29.9 bcd
Pickled	31.7 cd	22.8 cdB	39.3 abcA	40.2 bc	25.6 bcde
Brined (in salt solution)	20.6 e	16.3 d	24.3 cde	28.0 c	15.4 e
I do not want to eat seaweed	4.0 f	4.3 de	3.7 f	0.0 d	6.8 ef

^aStale, aquarium fish food, mud lakebed (Swedish: dybotten), crispy/chips (n = 3), crunchy (n = 2), chewing resistance, cartilage (n = 2), intense, gel.

^bSalad (n = 2), bread/crispbread (n = 3), pesto, drink, soup, food for training occasions (bar, shake), or dish complements.

^cAll (n = 10), stupid question, modern Swedish food, food fusion.

^dDried whole or in pieces, As an ingredient in dishes (n = 3) such as burgers or sausages, Stir-fried, fried or deep-fried (n = 2).

than Generation X and Baby Boomers to associate these constraints with seaweed.

Participants were then asked to include seaweed in the “food circle” (Table 2), a Swedish dietary guideline model developed by the Swedish Food Agency, which encompasses categories of foods important for a balanced diet. In this context, seaweed was most frequently categorized as a *vegetable* (n = 145, 72.9%), followed by a protein source, such as *meat, fish, egg, legumes, nuts, and seeds* (n = 27, 13.6%).

Finally, the participants’ most important health claims for an increased acceptance towards seaweed consumption (Table 2) included a *good source of minerals* (n = 120, 60.3%), *good amino acid profile / good protein quality* (n = 82, 41.2%), *high protein content* (n = 69, 34.7%), and *high fiber content* (n = 67, 33.7%).

3.3. Environmental sustainability aspects

Seaweed refers to a diverse group of species and terminologies (Table 3). The participants were most familiar with the terms: *seaweed* (n = 186, 93.5%), *algae* (n = 183, 92.0%), *nori* (n = 148, 74.4%), *kelp* (n = 137, 68.8%), *sea lettuce* (n = 118, 59.3%), *wakame* (n = 109, 54.8%), and *sugar kelp* (n = 107, 53.8%), and less familiar with the terms: *kombu, dulce, Ulva, sea vegetables, and bacon of the sea*. The participants were more familiar with the trivial name of a green seaweed variety (sea lettuce) than with its Latin name (*Ulva*). Some participants added *spirulina, rørhinna* (Swedish trivial name for *Ulva intestinalis*; n = 2), *superfood of the sea* (which they specified as an incorrect term), *bladderwrack* (n = 2), *tare, carrageenan, and agar* to this list of familiar terms in the free text answer. Consumers who regularly eat seaweed are more familiar with the less commonly known terms – wakame, sugar kelp, kombu,

Table 5

The table presents thematic groups, and example quotes from the open-ended question (Q16): “ [...] what would be your favorite food with seaweed?”. Comments are translated from Swedish to English by the authors.

Thematic groups	Example quotes
Southeast Asian-Inspired Dishes	“Sushi or other Asian food that traditionally contains seaweed” “No direct favorite food, but food that already has associations with the sea, or in Asian food as a flavor-enhancer (umami)”
Seafood Dishes	“Seaweed with fish or shellfish is delicious. Roll seaweed, such as rørhinna, into a plaice fillet and bake in the oven. Serve with roasted Jerusalem artichoke, shellfish sauce and parsnip puree. It's delicious. Seaweed goes well with Asian flavors. Preferably with soy and sesame oil as ingredients in sauces.” “Some form of seaweed patties / buns”
Soups, Stews & Stir-fries	“Seaweed soup and delicious bread with seaweed raw material.” “Probably as a raw material similar to vegetables, i.e. both in stews and salads, but also as a side dish similar to pesto, mayonnaise or coleslaw.” “There are lots of good things, but the favorite is probably “stir-fried” finger-kelp, dried / oven-roasted crispy bladderwrack and bladders.”
Vegetable-based Dishes	“I mostly associate seaweed with sushi. So, I don't know. But if you could put seaweed in a veggie-burger, it could probably be a favorite.” “A substitute product to replace fish from classic fish-based dishes.” “Raw material to cook yourself. For most things... Seaweed as seaweed. Not interested in processed fake food.”
Pasta, Rice & Grain Dishes	“A main course where the seaweed could be both the “pasta” and the sauce or pickled seaweed” “Dried ground seaweed as a spice, to use in fish soups, fish sauces and pasta dishes and pizza.”
Salads & Side-dishes	“Salad, combined with other raw materials.” “We made a potato salad with fresh potatoes and bladderwrack-shoots and olive oil, lemon and capers. Dried in salt, and mixed into a salad with lentils, peppers, tomatoes, red onions, maybe halloumi or mozzarella? Or as a sea pesto.” “As a salad component or side vegetable (really anything that makes it taste good).” “In Asian food as a flavoring. It would also be interesting as chips for a side dish, something crunchy & salty.”
Snacks & Breads	“I tasted oat milk ice cream with seaweed syrup and a caramelized alga last summer. The syrup was ok, but probably due to the large amount of sugar. The caramelized seaweed had an intense seaweed flavor that I find more suitable for a salty snack.” “Crispy chips as a snack.” “Bread with seaweed, topping / spread on seed cracker, seaweed pesto” “Why not seaweed crispbread?”
Sensory Enhancers & Additives	“Can't pick one. I like to toss a little kelp into boiling legumes to add flavor and depth. I also really like to use red algae to season mushrooms. In a beluga lentil bouillabaisse, I really like some Ulva. So, it depends, I also really like to make sloe jelly with Chondrus crispus. [...]” “Mixed in everything, as a nutritional boost. [...] And it would be great if you could bake cheesecake or something similar with seaweed!”

dulse, *Ulva*, sea vegetables, and bacon of the sea – compared to those who rarely consume it. Similarly, younger consumers (Generation Z and Millennials) demonstrated greater familiarity with several of these lesser-known terms than older age groups (Generation X and Baby Boomers).

In relation to the protein shift (Table 3), most consumers were interested in a *new protein-rich product* (n = 131, 65.8%), followed by a *flavor enhancer sauce or powder (to consume more legumes and vegetables)* (n = 115, 57.8%), *protein-rich product based on whole seaweed pieces or powder* (n = 105, 52.8%), and *protein-rich product based on seaweed protein extract* (n = 80, 40.2%). Only 3.5% (n = 7) did not think that

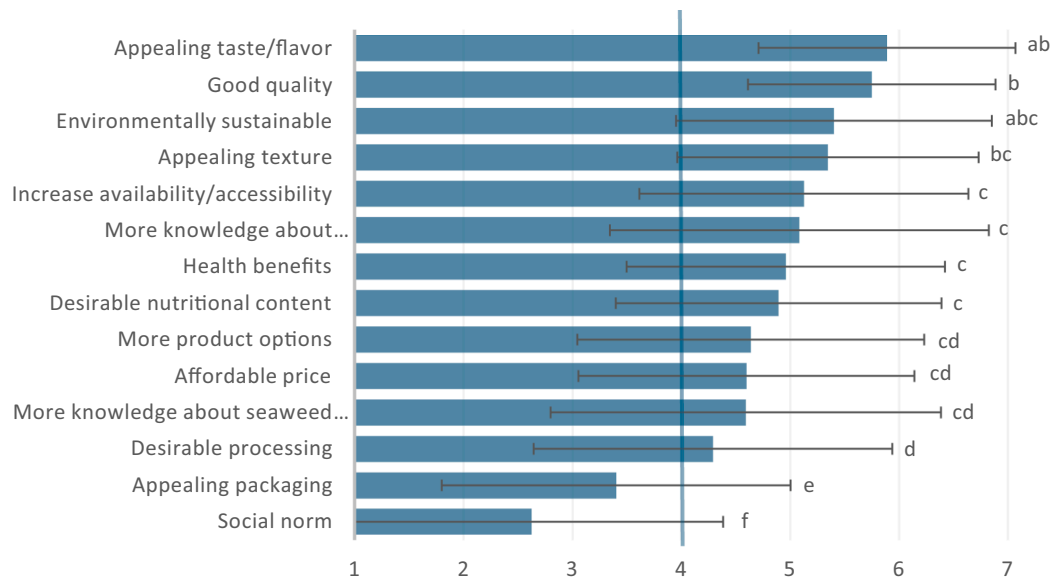


Fig. 2. Study participants' ($n = 199$) answers to the questions (Q17–30) “How important are the following reasons in motivating you to eat seaweed?”, on a 7-point scale ranging from “not important” (1) to “very important” (7). Results are reported as mean values with standard deviation. Significant differences (Tukey's, $p < 0.05$) between the answer options are indicated with letters (a-f).

4. Discussion

Participants in this study were mainly female, with an even age distribution, and with reported dietary preferences in line with the Swedish population (Axfood, 2024). As many as 41% reported eating seaweed regularly (monthly or more frequently), which is likely attributable to a higher response rate among individuals with a particular interest in seaweed. Previous studies have indicated a high interest in seaweed consumption, with 95% of participants expressing a positive attitude towards eating seaweed (Wendin and Undeland, 2020). This high level of interest was confirmed in the present study, with only 3–4% of participants expressing an unwillingness to consume seaweed as food. Evidently, in line with the theory of planned behavior (Ajzen, 1985, 1991), a large gap between intention (>95%) and behavior (41%) remains.

The following sections discuss three key factors influencing seaweed consumption – health, environmental sustainability, and sensory perception – followed by additional motivating aspects.

4.1. Health aspects

Seaweed is considered a nutritious food, largely due to its high content of minerals, dietary fiber, protein, and various bioactive compounds, including antioxidants (Holdt and Kraan, 2011). In Sweden, the Food Circle serves as a dietary guide to illustrate how a varied intake can help meet the human daily nutritional requirements (Swedish Food Agency, 2025). Within this framework, the participants categorized seaweed alongside vegetables, which are, just like seaweed, generally rich in fiber, vitamins, minerals, and antioxidants. These results can inform the understanding of the food environment related to seaweed within the framework of the socioecological model (Fernqvist et al., 2024). Next to vegetables, most participants categorized seaweed with meat and fish, which can guide retailers in how to place the seaweed in the store. In Japan, for instance, some seaweed products are sold fresh in the refrigerated seafood counter.

In this study, claims such as high mineral content, good protein quality, and richness in protein and fiber were identified as key factors motivating seaweed consumption. These are factors related to the food environment level according to the socioecological model (Fernqvist et al., 2024). This is particularly relevant for producers and marketers,

as it highlights opportunities to make health and nutrition claims about seaweed-based products that are reported as relevant to these consumers. Conversely, seaweed was frequently associated with the presence of heavy metals. However, this perception did not appear to significantly influence its association with toxicity. In line with this, some consumers expressed a need for clearer information and increased awareness regarding appropriate quantities and preparation methods to ensure safe consumption.

4.2. Environmental sustainability aspects

Environmental sustainability is reported as a strong motivator for seaweed consumption (Wendin and Undeland, 2020; Young et al., 2022) and is communicated through a range of pro-environmental claims (van den Burg et al., 2019). This was confirmed in the present study, which further emphasizes the importance of key claims such as being ecosystem-friendly, natural, free from herbicides, and locally sourced. Interestingly, while ecosystem services were considered the most important, increased biodiversity, a similar concept, was reported as the least important. This understanding of the participating consumers' perspectives can be particularly useful for producers and marketers.

The knowledge of seaweed as a marine raw material varied widely, from those who primarily recognized it as a sushi ingredient to those who could differentiate and name various species. In cultures lacking a strong culinary tradition with seaweed, such as in Sweden, it appears more common to use general terms like 'seaweed' or 'algae' to describe these sea vegetables rather than their specific species names, unlike in Japan, for instance, where different seaweed types and preparation forms have unique names (Mouritsen et al., 2018). This can be compared to the broad terms used for land-based crops, where vegetables are generally differentiated into specific types or varieties. While seaweed and algae were still the most familiar terms in this study, participants were largely familiar with more specific terms, such as nori, (sugar) kelp, and sea lettuce. However, participants seemed more familiar with trivial names (sea lettuce) than their Latin names (*Ulva*). Participants were knowledgeable about the fact that seaweed, if grown in unfavorable conditions, can contain heavy metals and high iodine levels, which limit the recommended daily intake (EFSA et al., 2023; Jacobsen et al., 2023; Jönsson and Nordberg Karlsson, 2024). However, seaweed was not widely associated with toxicity.

Table 6

The table presents thematic groups in relation to the socioecological model's food choice levels (Bronfenbrenner, 1977, 1979; Fernqvist et al., 2024) and example quotes from the question (Q31): "Do you have any other thoughts on important motivators for you to facilitate eating seaweed?". Comments are translated from Swedish to English by the authors.

Thematic group	Food choice level (Bronfenbrenner, 1977, 1979; Fernqvist et al., 2024)	Example quotes
Education and cooking knowledge	Individual level (where education may be driven by the outer levels – food environment, social/community, or interpersonal)	<p>"Need more knowledge. I eat quite a lot already today but would eat more if I knew more about cooking."</p> <p>"That it is safe, that there are recommendations for how much we can eat as it is difficult for the body to break down. Clear cooking instructions so that you do not lose nutrients due to incorrect cooking"</p>
Advertising and awareness	Food environment level (promotion and store environments)	<p>"I just want to confirm that availability (with advertising in the store) and recipes are some of the most important things. I know too little about seaweed and since I'm an omnivore, it has to come my way for me to think of it as food. Obvious choice in some Asian dishes..."</p> <p>"Easily available in stores. Easy to prepare and use. Good communication in stores. Clear areas of use for different products."</p>
Availability and accessibility*	Food environment level (food availability)	<p>"Taste and smell are important. When I ate the seaweed, although crunchy and somewhat tasty, the strong smell made me think of some landscapes... and the piles of seaweed on the seashore... which don't seem well-kept, and I personally don't feel good when I pass by there."</p> <p>"I don't want to risk ruining a dish by pouring in algae. I don't know how the taste 'marries with' other flavors."</p>
Sensory characteristics	Food environment level (food characteristics)	<p>"As someone who eats seaweed often, I especially miss locally grown alternatives."</p> <p>"Balanced communication about health benefits. How much is realistic to eat in relation to health benefits"</p>
Sustainability and ethics	Social and community level (norms and culture)	
Health	Individual level and food environment level (food characteristics)	

* Availability refers to whether seaweed exists in a given area, while accessibility describes how easily it can be obtained and utilized.

As a component in the protein shift, participants would rather see a new product, such as fish/meat replacement, a flavor-enhancer for enhancing the taste and flavor of other green proteins, or a product with whole seaweed pieces, such as protein-rich salad, bread, or smoothie, rather than a more processed product. This was also expressed in the free comments, where several participants expressed interest in seaweed as a fresh raw material. However, there appeared to be two consumer segments: one that wants to highlight seaweed flavors in dishes, potentially complementing or replacing fish, and another that wants to mask the flavors, such as by using it as flour in bread. This may be represented by different consumer segments, "Food Enthusiasts" and "Food Conservatives", as described by Tomić Maksan et al. (2025), or "Progressive", "Conservative", and "Egoistic", as formulated by Govaerts and Olsen (2024). The results showed that frequent seaweed consumers (daily to monthly) are typically younger, female, and follow special diets like

vegan, lacto-ovo vegetarian, or flexitarian. This consumer group is more often guided by biospheric values (Govaerts and Ottar Olsen, 2023) and demonstrates greater openness to novel and sustainable food experiences compared to omnivores (Rosenfeld, 2018).

4.3. Sensory perception aspects

Participants' sensory perceptions of seaweed were primarily associated with saltiness, fresh sea, and umami. Previous sensory studies have shown that common descriptors across different species indeed include salty and umami tastes and marine flavors (Jönsson et al., 2023; Mouritsen et al., 2018). Worth noticing, the general term seaweed was used in this question, which may prompt the participants to make associations with the most common and available types, i.e., dried kelps or nori, and not, for instance, less common green seaweeds, which have more dominant flavors of green, spinach, and citrus (Jönsson et al., 2023; Trigo et al., 2024). Overall, the participants inquire about more information to increase their knowledge and hence their consumption of seaweed.

In addition to increased knowledge about seaweed raw material, participants request more information on how to use seaweed for food. It is apparent that most consumers still associate seaweed with sushi and Southeast Asian cuisine, but are open to including it in other cuisines, such as the Nordic, Mediterranean, and traditional Swedish (husmanskost).

Overall, most participants preferred to incorporate seaweed into savory foods such as main dishes, salads, seafood, starters, side dishes, soups, snacks, or as sensory enhancers. To facilitate usability, the participating consumers request more knowledge on how to use seaweed, such as through recipes and home-cooking techniques, shared via various media channels. This is also confirmed among US consumers (Zheng et al., 2024). However, a recent study has demonstrated how culinary workshops improved seaweed cooking skills, seaweed attitude, and seaweed self-efficacy more than access to recipes and products (Lafeuille et al., 2024).

4.4. Motivators for increased consumption

While the general interest in seaweed for food is high, several motivators/enablers can improve consumer acceptance of seaweed further and fill the gap between intention and behavior (Ajzen, 1991). The most important motivators for increased consumption were reported as appealing taste, good quality, environmentally sustainable, and appealing texture, aligning with previous consumer research in France (Lucas et al., 2019), Italy (Palmieri and Forleo, 2020), the USA (Zheng et al., 2024), Australia (Birch et al., 2019a; Young et al., 2022), New Zealand (Rombach and Dean, 2024), and Mexico (Tenorio-Rodríguez et al., 2025). According to the socioecological model (Fernqvist et al., 2024), these motivators operate at both the individual and food environment levels, while the interpersonal and societal levels, particularly social norms, are self-reportedly perceived as less influential.

Progressive consumer segments value the environment highly and are more likely to consume seaweed than other segments (Govaerts and Olsen, 2024). The perception of an appealing texture can vary among consumers, with some preferring soft textures and others liking it crunchy. Moreover, participants value good quality, but it is unclear whether consumers are aware of what constitutes good quality and how it is expressed. In societies with strong seaweed culinary culture, such as in Japan, the consumer is generally knowledgeable about quality differences, such as color differences and the texture of nori sheets, and retailers offer products at various quality levels (Isaka et al., 2015; Mouritsen et al., 2018). Quality in terms of health and nutrition could benefit from claims such as good sources of minerals, good protein and amino acid content, as well as high fiber content. Finally, thematic clustering emphasized the need for more knowledge, availability, advertising, and awareness, including practical guidelines and recipes,

for increased seaweed consumption.

4.5. Future aspects and limitations

Based on the findings of this study, several recommendations can be made for the emerging seaweed industry and its stakeholders. Efforts should be directed toward expanding the knowledge base of seaweed as a raw material by distinguishing between species and providing clear information on nutritional value, health benefits, and recommended daily intake. Increased visibility through TV shows, media, in-store promotion, and other awareness-building channels is requested by consumers. Product positioning should be adapted to different consumer segments, considering whether seaweed is best highlighted or subtly incorporated into products. The lack of a strong seaweed tradition in many Western countries, such as in the case of Sweden, could be viewed as an opportunity for innovative market development.

This study is subject to some limitations that should be acknowledged. First, as in the case of all survey studies, certain demographic groups were difficult to reach, which means the sample cannot fully represent the broader Swedish population. For example, participation was higher among women than men, and the survey was primarily distributed through the research group's social media channels and university networks. As a result, the generalizability of the findings is limited. In addition, this study appeared to attract individuals with an already high interest in seaweed. Future studies could aim to include an even larger and more diverse sample of consumer segments to enhance generalizability and capture a broader range of attitudes and behaviors. Second, while the use of open-response option questions within the CATA (Check-All-That-Apply) format offers valuable insights and allows participants to express views beyond predefined categories, it also presents challenges such as a lack of depth, response bias, and quantification issues. Hence, this study could be complemented by qualitative components in future research as well as by studies on an international level, comparing different cultures. Lastly, analyses based on subgroups within the sample suffer from lower statistical power.

5. Conclusion

This study has provided insights into the current knowledge and acceptability among Swedish consumers toward seaweed as a food in a future diet. Participants were knowledgeable of seaweed as a rich source of certain micro- and macronutrients, as well as a flavor carrier of saltiness, umami, and marine freshness. Environmental sustainability remained an important factor for seaweed consumption, particularly driven by seaweed being ecosystem-friendly, natural, locally sourced, and grown without herbicides. Key concerns included potential contamination with heavy metals and iodine, which are aspects currently addressed at the national and EU levels. The results further showed a positive attitude towards seaweed as food, while current consumption is relatively low, indicating a gap between intention and behavior, in line with the theory of planned behavior. Several factors were identified as important motivators for filling this gap, including appealing sensory attributes, product availability, sustainability, nutritional value, and overall quality. Respondents also emphasized the need for increased visibility through media, in-store promotions, and other awareness-raising strategies to support broader adoption. While some consumers prefer to hide seaweed in familiar foods, others appreciate highlighting its distinctive qualities in dishes. Although participants are primarily familiar with seaweed through sushi and other elements of Asian cuisine, many expressed openness to its use in a broader culinary context, such as a substitute for fish or meat, or as a flavor enhancer in various dishes. These findings provide valuable insights into consumer knowledge and attitudes toward seaweed for informing future directions in product development, strategic marketing, and sustainable production systems, with the overarching aim of enhancing the integration of seaweed into Western diets.

Ethical considerations

This study was granted ethical approval by the ethics board at Kristianstad University, Sweden (Nr. 2024–2.3.4–724). All participants received written information about the test and gave their informed consent to participate. Participation was voluntary, and participants could withdraw at any time without providing any reasons. Information from the questionnaire cannot be traced to or used to identify any individual participant, in accordance with the EU's General Data Protection Regulation (GDPR). Microsoft Copilot (GPT-4-turbo, USA) has been partly used for language review of the paper.

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CRediT authorship contribution statement

Madeleine Jönsson: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Marcus Johansson:** Writing – review & editing, Software, Methodology, Conceptualization. **Mar Vall-Ilosera:** Writing – review & editing, Conceptualization. **Sophie Steinhagen:** Writing – review & editing, Funding acquisition, Conceptualization. **Ingrid Undeland:** Writing – review & editing, Project administration, Funding acquisition, Conceptualization. **Karin Wendin:** Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

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

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Data availability

Data will be made available on request.

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