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To cite this article: Jennifer C. Griffiths, Charoula K. Nikolaou & Jessica M. M. Adams (2026) Seaweed on my lunch tray: challenges and opportunities for including macroalgae in Welsh school meals, *Applied Phycology*, 7:1, 2605065, DOI: [10.1080/26388081.2025.2605065](https://doi.org/10.1080/26388081.2025.2605065)

To link to this article: <https://doi.org/10.1080/26388081.2025.2605065>



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Published online: 19 Jan 2026.



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# Seaweed on my lunch tray: challenges and opportunities for including macroalgae in Welsh school meals

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## ABSTRACT

The inclusion of seaweed in European school meals would be atypical but offers a great opportunity to enhance childhood nutrition, support local livelihoods, preserve the use of traditional foods and contribute to sustainability targets. Seaweeds provide a source of iron and B vitamins whilst being low in fat, sugar and calories; they are also a whole-food, animal-free food providing umami flavouring. In this study, focusing on school meals in the UK region of Wales, seaweed is not currently included in meals and its limited availability within wholesaler catalogues and the relatively high cost prevent its inclusion. To realize the multiple benefits of this ingredient, demand should be boosted, which will lead to increased supply and bring seaweed within catering budgets. Increasing demand should encompass a clearer quantification of nutritional benefits, a communication of the benefits to current dietary patterns, provision of a playbook of suitable uses in school and home kitchens and a greater inclusion in wholesaler catalogues supplying caterers. Combined, these actions would create a future of more nutritious meals for Welsh children that would provide holistic support for wider ecological, social and economic systems.

## ARTICLE HISTORY

Received 19 May 2025  
Accepted 1 December 2025

## KEYWORDS

Aquaculture; childhood nutrition; micronutrients; nutrition; plant-based; *Porphyra*; school meals; sustainable diets

## Introduction

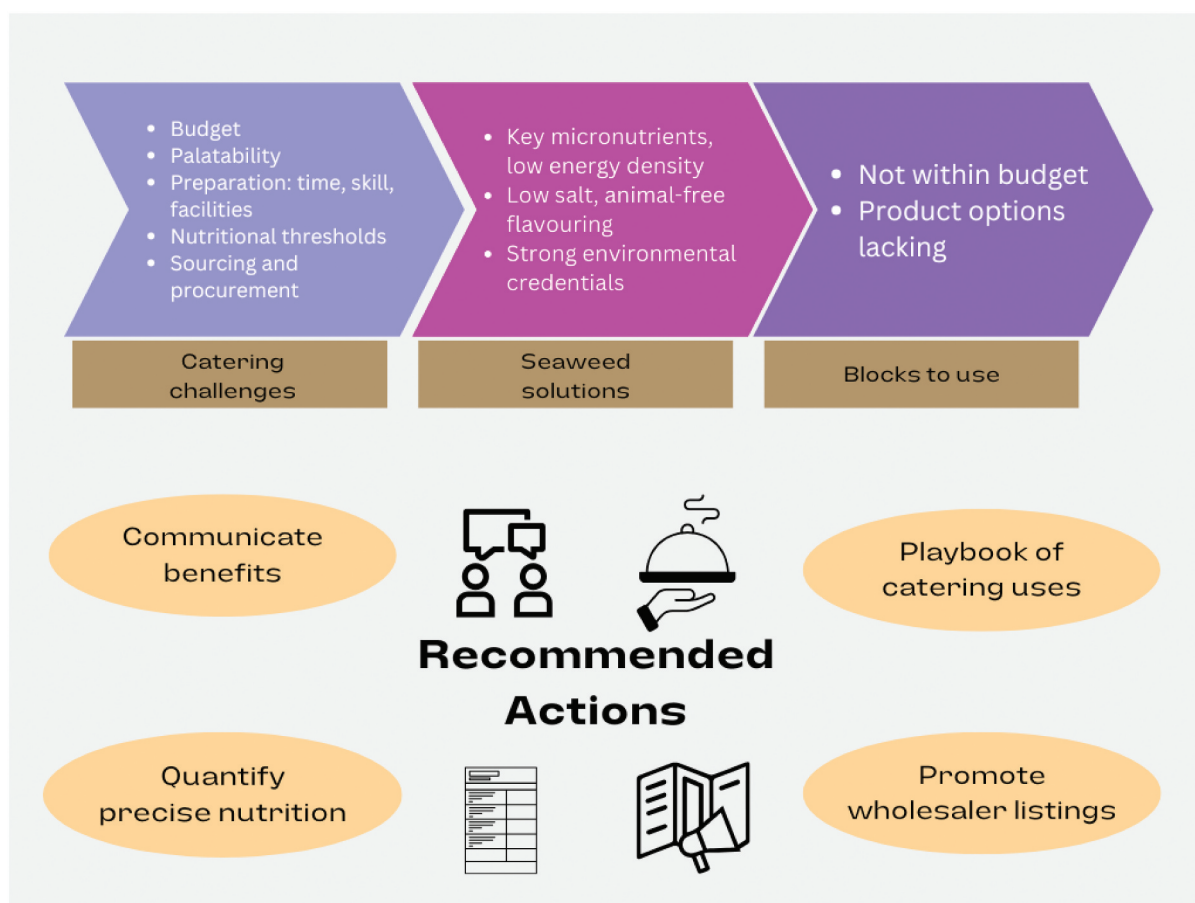
Europe has committed to working towards the Sustainability Goals of the UN 2030 Agenda for Sustainable Development, encompassed in a range of policies towards supporting greater wellbeing and thriving economies (European Commission, 2025). There is a focus on net zero through the European Green Deal, which aims to bring net emissions to zero by 2050 (Fetting, 2020). Food systems are considered within this in the Farm to Fork Strategy (European Commission, 2020), prioritizing the need to respect provenance and make appropriate use of natural resources to ensure high quality, continued food provision. Responding to recent food system shocks, such as the COVID-19 pandemic, unstable political regimes and climate change requires novel approaches to ensure resilience within individual countries (Poczta-Wajda & Poczta, 2024).

Wales (a country in the UK) replicates and demonstrates these aims in its commitment to supporting its population to thrive, solidified in the Wellbeing of Future Generations Act (National Assembly for Wales, 2015) and enhanced by its provision of nutritionally regulated universal free meals in all government-maintained primary schools (Welsh Government, 2014, 2024b). Globally, school meals are documented to have the potential to improve children's health across all socioeconomic backgrounds during a critical period of life (Kenton-Lake et al., 2021; Pastorino & Springmann, 2023) refer to Fig. 1. This provision is aimed at tackling the public health crisis of childhood obesity in Wales, currently standing at 11.4%, and improving dietary quality (Public Health Wales, 2023). The Wellbeing Act also considers global responsibility and resilience, with food systems increasingly being recognized as an area for improvement (Willett et al., 2019). Free school meals adhere to specific nutritional parameters (Welsh Government, 2024a). Thresholds are for key micronutrients and limits are on excessive fat, salt and added sugars (Table 1). These meals are non-means tested and optional (i.e., children may opt out and bring their own food if desired).

Catering staff must balance food preference, budget, sourcing, time and skills to fit these criteria (Bryant et al., 2023), which places pressure on them to provide meals that fit within nutritional and environmental

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**Fig. 1.** The main challenges facing greater inclusion of seaweed in school meals and the key recommended actions needed to achieve this.

**Table 1.** Requirements of school meals as set by the Welsh Government (2014).

Nutrient	Requirement per portion for primary school lunch
Energy (kcal)	530 ( $\pm 5\%$ )
Total fat (g)	<20.6
Saturated fat (g)	<6.5
Total carbohydrate (g)	>70.6
Non-milk extrinsic sugars (g)	<15.5
Fibre (g)	>4.2
Protein (g)	>7.5
Iron (mg)	>3.0
Zinc (mg)	>2.5
Calcium (mg)	>193
Vitamin A ( $\mu\text{g}$ )	>17.5
Vitamin C ( $\mu\text{g}$ )	>10.5
Folate ( $\mu\text{g}$ )	>53
Sodium ( $\mu\text{g}$ )	>499

boundaries (Bone & Kejriwal, 2021). Nutrition requirements, allergen awareness and dietary preferences must also be considered and balanced with budgeting costs, for which a free licence for an analytics tool is provided by the government (Creed Food Service, 2022). Minimizing food waste through correct portioning and palatability of foods can both make more efficient use of funds and contribute to sustainability aims. There is also a recognition of the importance of local sourcing and ‘sustainability’ of ingredients where possible (Food Sense Wales, 2023; Hacking, 2022).

Macroalgae (seaweed) offer many benefits when included in the diet. Seaweed is an animal-free source of nutrients and fibre. Most notably, this includes micronutrients such as iron, vitamin B12 and zinc that might

otherwise be difficult to include in adequate amounts in nutritionally controlled meals. Seaweed provides a source of omega-3 fatty acids (Box 1), fibre and protein whilst containing relatively few calories (less than 7 kcal per 5 g portion) (McCance & Widdowson, 2021; Public Health England, 2021). Furthermore, macroalgae typically have a relatively high glutamic acid content, as much as 2000 mg per 100 g dry weight (Milinovic et al., 2021). This adds an umami flavour to foods, providing potential use as a natural flavour enhancer (The Umami Information Center, 2024). Using seaweeds can, therefore, replace some or all of the salt normally added to some dishes without negatively affecting flavour (Carrascal et al., 2016) and develop a richer flavour profile for meat-free meals (Mouritsen, 2023; Schmidt & Mouritsen, 2022). As a non-animal food that does not compete with land or freshwater resources (Duarte et al., 2021), seaweed fits well within the recommendations for diets with lower planetary impacts (with a low percentage of animal-source foods and from local, sustainably operating sources) such as the landmark publications by non-profit global commission EAT (Willett et al., 2019).

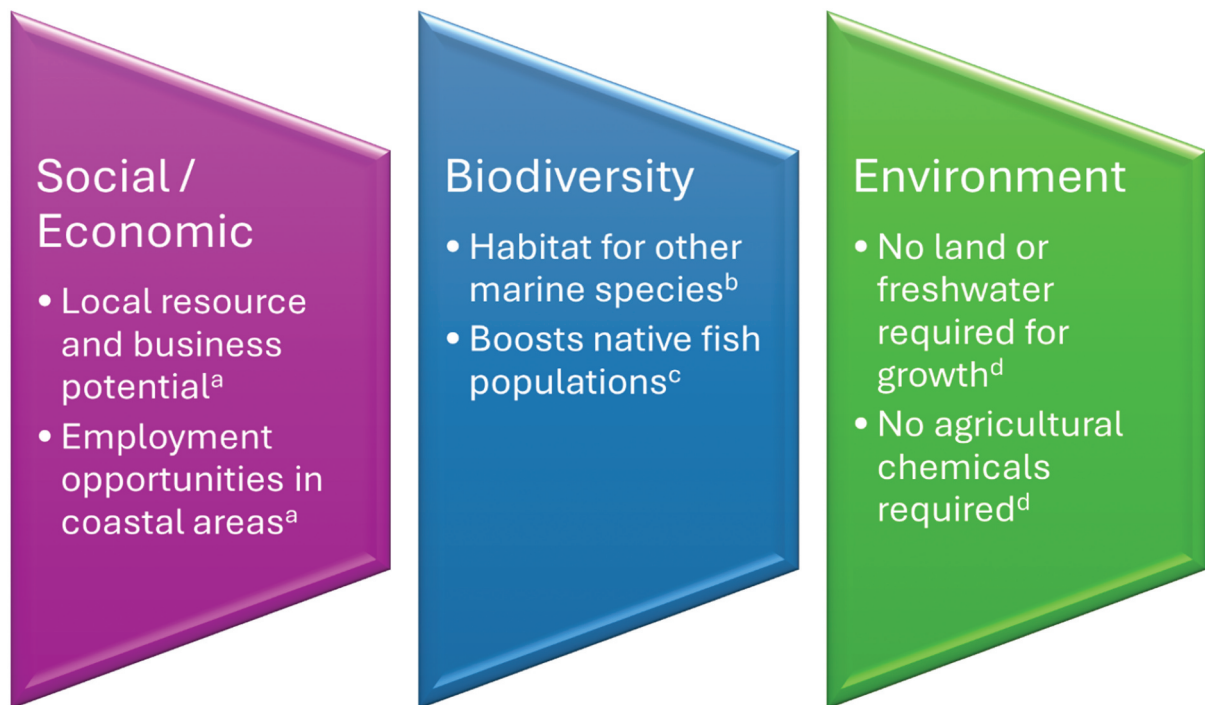
Macroalgae have been historically used as part of traditional medicine and for therapeutic cosmetics (Fleurence & Levine, 2016; O'Connor, 2018), and more recently studied for their potential role in treating more recently recognized health conditions such as diabetes and cancer (Fleurence & Levine, 2016; Peñalver et al., 2020). Extracts are increasingly being used in the nutraceuticals and functional food market as a beneficial fibre for gut health (Lee et al., 2025). Recent studies have indicated that compounds in seaweed such as laminaran and fucoidan can also aid in the prevention of metabolic diseases such as hypertension and Type II diabetes, support a healthy gut microbiome, shrink certain types of cancer tumours and treat specific viral diseases (Brown et al., 2014; Lee et al., 2025; Pérez-Lloréns et al., 2023; Trigo et al., 2023).

As well as potentially improving the nutritional content of human diet (Fig. 2), seaweeds can contribute to responses to many other global challenges. Sustainable development using marine and aquatic resources, creating a blue bioeconomy, has become a recognized pathway towards economic and regional development in Europe (European Commission, 2021; Kontovas et al., 2022). There is potential for seaweed in a wide range of industrial products, including bio-pesticides, biodegradable plastics and biostimulants, offering a means for positive development of circular processing that can contribute to sustainability aims (Yong et al., 2022, 2024). Scotland's 2015 National Marine Plan for sustainably developing its coastal areas is also working towards maximizing these marine bio-economy opportunities (Wilding; Scottish Government, 2015). As evidenced by Car-y-Mor and Aird Fada Seaweed Farm, community-owned regenerative seaweed and shellfish farms based in Wales and Scotland respectively, enterprises need not take traditional corporate routes and may operate in a more open, flat structure (Car-y-Mor, 2024; Farm, 2021).

As a part of regenerative ocean farming, aiming to support marine habitats, seaweed cultivation can support ecosystems by reoxygenating acidified waters, supporting lower-trophic species that may be directly

**BOX 1.** Seaweed as a source of Omega-3 fatty acids.

Seaweed's popularity has grown recently owing to its popular media focus, particularly in diets avoiding animal products, on its relatively high percentage of their fats being omega-3 polyunsaturated fatty acids (PUFAs), particularly in their DHA/EPA form (Jaworowska & Murtaza, 2023; Pereira & Valado, 2021; Yesuraj et al., 2022). These are important for cognition and brain health (Sinn et al. 2010; Cornish et al. 2017; Healy-Stoffel & Levant, 2018) and their abundance in certain fish due to their algae-rich diet (Rizzo et al. 2023) is a primary rationale for the NHS recommendation for two portions of fish per week, one of which should be oily (NHS, 2022). Vegetable-based sources of omega-3 are in the ALA form, which is converted in the body into DHA and EPA (Pereira & Valado, 2021; Saunders et al., 2013; Saini et al., 2021). This process is inefficient however (Saunders et al., 2013; Saini et al., 2021), and there is therefore great interest in the potential of consuming seaweeds by people who do not consume animal products as an alternative source of these fats (Nicolini et al., 2024; Rocha et al., 2021; Rizzo et al., 2023; Saini et al., 2021). Whilst it is true that seaweed contains high levels of PUFAs, this is as a percentage of the overall fat content. Seaweed is a low-fat food, so consuming it in its whole form would not provide vast amounts of dietary PUFA, ranging from 0.004–0.186 g per 100 g (Rizzo et al., 2023). Fat content also varies between species (Jaworowska & Murtaza, 2023), making the general term "seaweed" (or sometimes simply "algae", which also includes the wide range of microalgae organisms) far from meaningful (Lee, 2008). The high levels of PUFAs in oily fish arise from bioaccumulation and concentration through the food chain (Rizzo et al., 2023), thus the inclusion of fish in human diets is a more efficient means of increasing essential fatty acid intake. Regular consumption of small amounts of seaweed, however, would enable fortification of diets in a "drip-feed" manner (Peñalver et al., 2020).



**Fig. 2.** The multi-dimensional societal benefits of seaweed consumption (Bizzaro et al., 2022; Cai et al., 2021; Duarte et al., 2021); <sup>a</sup>(Albrecht & Lukkarinen, 2020; Bizzaro et al., 2022; Cai et al., 2021; Hasselström et al., 2018); <sup>b</sup>(Bizzaro et al., 2022; Cai et al., 2021; Duarte et al., 2021; Hasselström et al., 2018; Hurd, 2014); <sup>c</sup>(Bizzaro et al., 2022; Duarte et al., 2021; Hasselström et al., 2018; Hurd, 2014); <sup>d</sup>(Bizzaro et al., 2022; Cai et al., 2021; Duarte et al., 2021; Yong et al., 2022).

harvested and alleviating pressures from wild harvesting (Sultana et al., 2023; Yong et al., 2022). Some seaweeds are ecosystem engineers, e.g., habitat creation by the kelp *Laminaria hyperborea* (Corrigan et al., 2025), making it a key species for supporting a multitude of others and potentially contributing to healthier, more biodiverse seas (Hurd, 2014). In certain scenarios the act of seaweed farming itself may open up a market in blue carbon in the same way as environmentally sustainable land practices have developed a carbon trading scheme (Yong et al., 2022). Globally, seaweed farming now represents a substantial form of income and employment, having increased dramatically since 1950, now representing a market value of \$17 billion in 2021, which contributes towards UN sustainability goals as a farming technique that does not require the addition of fresh water, input or compete for land space (United Nations, 2024).

## Methods

### Case study area: Ceredigion

This study uses information from the mid-Wales county Ceredigion as an example to discuss benefits and possibilities of seaweed in school meals. Located in mid-Wales with the Welsh coastline on its western flank, Ceredigion has a population around 7 150 000 of which 13.2% are under the age of 15 (Ceredigion County Council, 2021). With over half of the population in some way classified as deprived and an employment rate of only 46.8% (Ceredigion County Council, 2021), the provision of nourishing, universal free school meals could receive a significant welcome from many households. The county contains 37 state-managed primary schools (Ceredigion County Council, 2025), which are bound by Welsh and UK government legislation on teaching curricular and general operations. Whilst broad recommendations are made by the Welsh Government (Welsh Government, 2024a), no specific meals or recipes are suggested. These can be designed by the schools or local councils as in Ceredigion (Ceredigion County Council, 2024).

## Literature study

A primarily desk-based research approach was adopted to address the research questions outlined – namely, the nutritional benefits of including seaweed in Welsh school meals, the existence of suitable products on the market, their availability to caterers, and associated cost implications. This involved a structured review of relevant literature, market analyses, and official data sources (Table 2). The literature review included searches of academic databases, industry publications and grey literature, with a focus on recent data to ensure the relevance and accuracy of findings. Particular attention was paid to studies concerning the nutritional profile of seaweed, its incorporation into school food settings, and its broader public health implications. Governmental and public sector datasets, including those relating to school meal standards and procurement frameworks in Wales, were consulted to provide context and policy alignment. Current wholesaler listings were reviewed to evaluate product availability and indicative pricing, allowing for a preliminary assessment of cost implications for public sector catering. The combination of data sources was chosen to triangulate findings and ensure that conclusions were grounded in both evidence and practice-based insight.

## Consultation-based data gathering

Targeted informal correspondence was carried out with key stakeholders to supplement and guide the enquiry. These included a specialist school caterer from Ceredigion County Council, who provided insights into local authority perspectives on school meal provision, a university caterer with sustainable menu design experience and a regional food wholesaler manager. These informal consultations were not intended as formal interviews but rather to inform the direction of the desk-based research, highlight practical considerations, and identify potentially overlooked market or logistical factors.

## Nutritional potential for school meals

When considering school meals, nutritional parameters must be understood in order to gauge ingredient impact on meal composition (Welsh Government, 2014). The current standard for food nutritional components in the UK is provided in the Composition of Foods Integrated dataset (CoFID), compiled by McCance and Widdowson (McCance & Widdowson, 2021; Public Health England, 2021). It has limited usefulness, however, in terms of seaweed through listing only five species, not all of which are native to the UK (Table 2). The inclusion of *Undaria pinnatifida* (Wakame) is interesting as, although farmed widely in Asia, and purchasable as an ingredient in the UK, it is regarded as an invasive species when growing wild off UK shores and cultivation or harvesting for sale is illegal (NNSS, 2020; NRW, 2018). Other common species that grow readily and may be foraged are not included in the dataset, limiting the extent to which it is possible to truly account for what impact the use of Welsh seaweeds might have if these could be used as ingredients (NRW, 2018).

## Data analysis

Data were analysed in Microsoft Excel (version 16.91, Microsoft Corporation).

**Table 2.** Key question topics and sources of information.

	Sources
Nutrition	Official UK nutrition dataset, national nutrition guidance for children, Welsh school meals government requirements and academic literature
Product options	Literature and market search (web and academic sources: Scopus, Web of Science, Google Scholar, Google)
Product availability	Wholesaler and seaweed producer catalogues (Castell Howell; Harlech Food Service; Bidfood; Celtic Foodservice; Car y Mor; The Pembrokeshire Beach Food Company; The Cornish Seaweed Company; Selwyn's Seafoods)
Cost implications	Calculations based on 5 g dried portion per meal

**Table 3.** Species of seaweed with the CoFID official UK nutrition metrics (McCance & Widdowson, 2021; Public Health England, 2021).

	Grown in Wales	Species name	Food Name
Included CoFID dataset	Yes	<i>Porphyra umbilicalis</i>	Laverbread coated with oatmeal
	Yes	<i>Chondrus crispus</i>	Seaweed, Irish moss, raw
	Yes	<i>Saccharina sp./Laminaria</i>	Seaweed, kombu, dried, raw; Sugar kelp
	Yes	<i>Porphyra sp.</i>	Seaweed, nori, dried, raw; Laver
	No	<i>Undaria pinnatifida</i>	Seaweed, wakame, dried, raw
Not in CoFID dataset	Yes	<i>Palmaria palmata</i>	Seaweed, dulse
	Yes	<i>Ulva lacuta</i>	Seaweed, sea lettuce
	Yes	<i>Alaria esculenta</i>	Seaweed, winged kelp/Atlantic wakame
	Yes	<i>Ulva intestinalis</i>	Seaweed, grass kelp
	Yes	<i>Himanthalia elongata</i>	Seaweed, sea spaghetti

## Results

### Nutrition in school meals

Using the CoFID dataset (McCance & Widdowson, 2021), the impact on nutrition that seaweed in school meals might have been estimated. Table 3 indicates the nutritional content of a modest (5 g) portion of dried seaweed to suggest the per-meal benefits of including this ingredient. This has then been compared to the UK advised daily intake for a ten-year-old (Public Health England, 2016) and the requirements placed upon Welsh schools (Welsh Government, 2014) to gauge application in meeting targets.

This has been expanded upon in Table 4, with a hypothetical example recipe using the spinach and chickpea curry that is currently served in Ceredigion schools (Ceredigion County Council, personal correspondence, 2025). The supposed nutritional gains of adding seaweed in this case are in increasing the provision of retinol and B12 from 0 to 24% and 138% of recommended daily intake respectively. With B12 often being problematic for meat-free diets, this increase may be of increased dietary significance for vegan children. It should also be noted that this has minimal impact on macronutrient values and thus does not increase the meal's added sugars, calorie or fat content.

The addition of even this small amount of seaweed, particularly *Porphyra* species (laver), would enhance the provision of protein, fibre, potassium, calcium, magnesium, iron, zinc and vitamin B12 in the diets of school children, as highlighted in green in Table 3. Literature suggests biotin, folate and pantothenate may also be high but insufficient data is available through the CoFID dataset to quantify its dietary significance (Fleurence & Levine, 2016; Peñalver et al., 2020; Sultana et al., 2023). A more thorough study of European seaweed potential to contribute to daily recommended allowances supports the use of seaweed in diets to supplement key micro-nutrients, summarized in Table 5 (Circuncisão et al., 2018).

Care may need to be taken when consuming seaweed that recommended levels of sodium and iodine are not exceeded (highlighted in red in Table 3). More information about concerns over the iodine content of seaweeds in Box 2. With appropriate recipe adjustment it is still feasible to maintain safe limits.

### Availability and cost

Suitable seaweed ingredients must be sourced for use in catering. After harvest, seaweed is usually washed and thoroughly cleaned before consumption. It may then be frozen, dried, or otherwise further processed, milled or flaked, before being packaged and marketed globally (Akomea-Frempong, 2022) (Table 6). It is also possible to preserve seaweeds by pickling or fermentation, which can enhance flavour; these processes are extremely limited in the UK and only two UK-origin products could be found in this search, perhaps indicating a gap in the product market (Seaweed, 2025) and Octopus's Garden (Todelli, 2025).

School caterers are constrained by budget, availability of products through wholesaler catalogues, time required for preparation and skill level of staff (Bone & Kejriwal, 2021; Givens, 2022). The provision by the Welsh government for the Universal Primary Free School Meals was £2.90 per meal in 2023 subject to a review given the high inflation and the rising ingredients costs (Wales Centre for Public Policy, 2023). As

**Table 4.** Nutritional content of a 5 g portion of dried seaweed, comparing CoFID data to dietary daily recommendations for a ten year old child and Welsh school meal requirements.

	Advised intake for ten-year-old per day	Welsh school meal req	Quantity in 5 g portion												% contribution to daily requirement (highlighted if over 5%)		% contribution of meal requirement (highlighted if over 10%)						
			Chondrus crispus			Porphyra sp. (laver)			Undaria pinnatifida (UK invasive)			Saccharina sp. (sugar kelp)			Chondrus crispus		Saccharina sp. (sugar kelp)		Porphyra sp. (laver)		Undaria pinnatifida (UK invasive)		
			Irish moss, raw	Irish moss, raw	Irish moss, raw	Kombu, dried, raw	Nori, dried, raw	Wakame, dried, raw	Kombu, dried, raw	Nori, dried, raw	Wakame, dried, raw	Saccharina sp. (sugar kelp)	Saccharina sp. (sugar kelp)	Saccharina sp. (sugar kelp)	Irish moss, raw	Irish moss, raw	Irish moss, raw	Nori, dried, raw	Nori, dried, raw	Wakame, dried, raw	Wakame, dried, raw	Wakame, dried, raw	
Protein (g)	28.30	7.50	0.08																				
Fat (g)		max 20.60	0.01																				
Carbohydrate (g)	m 242 f 227.00	70.60																					
Energy (kcal)	m 1817.00 f 1703.00	530.00	0.40																				
Total sugars (g)		max 15.50																					
NSP (g)	20.00	4.50	0.62																				
Satd FA/100 g fd (g)		max 6.50																					
Poly FA/100 g food (g)	m 13 f 12		0.005																				
Sodium (mg)	2000.00	max 499.0	3.35																				
Potassium (mg)	2000.00		3.15																				
Calcium (mg)	550.00	193.00	3.60																				
Magnesium (mg)	200.00																						
Phosphorus (mg)	450.00		8.00																				
Iron (mg)	8.70	3.00	0.45																				
Copper (mg)	0.70		0.01																				
Zinc (mg)	7.00		0.10																				
Chloride (mg)	1800																						
Selenium (µg)	30.00																						
Iodine (µg)	110.00		0.10																				
Retinol (µg)	500.00	175.00	0.00																				
Retinol Equivalent (µg)	500.00	175.00	2.85																				
Vitamin D (µg)	10		0																				
Thiamin (mg)	0.70		0.00																				
Riboflavin (mg)	1.00		0.02																				
Niacin (mg)	m 12.00 f 11.20		0.03																				

(Continued)

**Table 4. (Continued).**

	Advised intake for ten-year-old per day	Welsh school meal req	Quantity in 5 g portion						% contribution to daily requirement (highlighted if over 5%)			% contribution of meal requirement (highlighted if over 10%)		
			<i>Chondrus crispus</i>	<i>Saccharina</i> sp. (sugar kelp)	<i>Porphyra</i> sp. (laver)	<i>Undaria pinnatifida</i> (UK invasive)	<i>Chondrus crispus</i>	<i>Saccharina</i> sp. (sugar kelp)	<i>Porphyra</i> sp. (laver)	<i>Undaria pinnatifida</i> (UK invasive)	<i>Chondrus crispus</i>	<i>Saccharina</i> sp. (sugar kelp)	<i>Porphyra</i> sp. (laver)	<i>Undaria pinnatifida</i> (UK invasive)
Vitamin B6 (mg)	1.00		0.00	0.00	0.00	0.00	0.05	0.35	0.05	0.05	0.05	0.05	0.05	
Vitamin B12 (µg)	1.00		0.14	1.38	0.13	0.13	14.00	137.50	12.50					
Folate (µg)	150.00	53.00												
Vitamin C (mg)	30.00	10.50								6.19	6.67	7.14		

Nutritional content of a 5 g portion of dried seaweed, as calculated from the official CoFID listings (McCance & Widdowson, 2021; Public Health England, 2021). This is compared to UK dietary daily recommendations for a ten year old (Public Health England, 2016) and Welsh government requirements for school meals (Welsh Government, 2014).

Male (m) and female (f) dietary requirements are identical unless stated.

Meal requirement values are minimum permitted unless stated as max (maximum).

Abbreviations: NSP – non-starch polysaccharides (regarded here as dietary fibre); Poly FA/100 g fd – polyunsaturated fatty acid per 100 g food; Sat FA/100 g fd – saturated fatty acid per 100 g food.

**Table 5.** Example meal.

	Portion of curry (239 g)	Curry +5 g dried nori	% contribution to daily intake		% contribution to school meal req	
			Curry	Curry with nori	Curry	Curry with nori
Protein (g)	9.1	9.1	32.16	32.16	121.33	121.33
Fat (g)	3.2	3.2			max 15.53	max 15.53
Carbohydrate (g)	28.3	28.3	m 11.69 f 12.47	m 11.69 f 12.47	40.08	40.08
Energy (kcal)	174	174	m 9.58 f 10.22	m 9.58 f 10.22	32.83	32.83
Total sugars (g)	8.2	8.2			max 52.9	max 52.9
NSP (g)	8.8	8.8	44	44	195.56	195.56
Satd FA/100 g fd (g)	0.12	0.12			max 1.85	max 1.85
Poly FA/100 g food (g)	0.49	0.49	m 3.77 f 4.08	m 3.77 f 4.08		
Sodium (mg)	389.5	389.5	19.48	19.48	max 78.06	max 78.06
Potassium (mg)	289.8	289.8	14.49	14.49		
Calcium (mg)	113.4	113.4	20.62	20.62	58.76	58.76
Magnesium (mg)	40.7	40.7	20.35	20.35		
Phosphorus (mg)	117.8	117.8	26.18	26.18		
Iron (mg)	2.7	2.7	31.03	31.03	90	90
Copper (mg)	0.23	0.23	32.86	32.86		
Zinc (mg)	0.99	0.99	14.14	14.14		
Chloride (mg)	0	0	0	0		
Selenium (µg)	2.8	2.8	9.33	9.33		
Iodine (µg)	0.08	73.58	0.07	66.89		
Retinol (µg)	0	0	0	0	0	0
Retinol Equivalent (µg)	0	124	0	24.8	0	70.86
Vitamin D (µg)	0	0	0	0		
Thiamin (mg)	0.05	0.062	7.14	8.86		
Riboflavin (mg)	0.03	0.097	3	9.7		
Niacin (mg)	0.02	0.295	m 0.17 f 0.18	m 2.46 f 2.63		
Vitamin B6 (mg)	0.63	0.6335	63	63.35		
Vitamin B12 (µg)	0	1.375	0	137.5		
Folate (µg)	36.3	36.3	24.2	24.2	68.49	68.49
Vitamin C (mg)	16.4	17.1	54.67	57	156.19	162.86

**SPINACH AND CHICKPEA CURRY - standard**

Ingredients for 10 Portions

1 tbsp. Mild Curry powder

2 tbsp. Tomato Paste

2 cloves of Garlic- crushed

2 Medium sized Onions –chopped

2 x 400g Tomatoes –chopped

1x 800g cans chickpeas –drained and rinsed

500g bag baby leaf spinach

Squeeze of Lemon juice

½ tsp Turmeric

**SPINACH AND CHICKPEA CURRY – with nori**

Ingredients for 10 Portions

1 tbsp. Mild Curry powder

2 tbsp. Tomato Paste

2 cloves of Garlic- crushed

2 Medium sized Onions –chopped

2 x 400g Tomatoes –chopped

1x 800g cans chickpeas –drained and rinsed

500g bag baby leaf spinach

Squeeze of Lemon juice

½ tsp Turmeric

**50g Dried Nori**

Nutritional content of a spinach and chickpea curry with and without 5 g portion of dried seaweed (nori, *Porphyra* sp.), as calculated from the official CoFID listings (McCance & Widdowson, 2021; Public Health England, 2021) and a recipe nutrition calculator (MyFoodData.com, 2025). This is compared to UK dietary daily recommendations for a ten year old (Public Health England, 2016) and Welsh government requirements for school meals (Welsh Government, 2014). Differences are noted as orange text.

Male (m) and female (f) dietary requirements are identical unless stated.

Meal requirement values are minimum permitted unless stated as max (maximum).

Abbreviations: NSP – non-starch polysaccharides (regarded here as dietary fibre); Poly FA/100 g fd – polyunsaturated fatty acid per 100 g food; Sat FA/100 g fd – saturated fatty acid per 100 g food.

indicated in Table 6, cooked and dried forms of algae would therefore be the most feasible from a costing and preparation perspective for considering as ingredients in school meals.

The product search through wholesaler catalogues in April 2024 for school caterer options showed that these are extremely limited with only one suitable item; seaweed is entirely absent from the catalogues of key competitors in Wales (Table 7). Suppliers of dried products are limited to specialists, foragers or seaweed farmers. Seaweed products are therefore more suitable for domestic kitchens or restaurant establishments that are able to offer niche menus.

Availability of products is also hampered by the minimal seaweed farming activity in the UK. For example, in 2025, Wales has only one commercial seaweed farm ([www.carymor.wales](http://www.carymor.wales)). To meet national

**BOX 2.** Iodine levels in seaweed.

The mineral iodine is used by the human body in the synthesis and healthy functioning of thyroid hormones, which are essential for metabolism (National Institutes of Health NIH Office of Dietary Supplements, 2022). As it is not produced in the body it must be obtained through the diet, with commonly recommended sources being fish, eggs and dairy products (Nicol et al., 2024). It is especially important for pregnant and breastfeeding mothers to meet iodine requirements due to its essential role in growth and development of the brain and nervous system, with deficiencies at this stage associated with impacting the infant as increased likelihood of infant mortality, stunted growth and cognitive impairment (National Institutes of Health (NIH) Office of Dietary Supplements, 2022; Smyth 2021). Deficient adults experience disrupted metabolism and are particularly at risk if they do not consume animal products or if they eat foods primarily farmed in soils with low iodine levels (Chan School of Public Health, Harvard, 2023).

Whilst excessive intake of iodine can equally cause metabolic problems (Chan School of Public Health, Harvard, 2023; National Institutes of Health (NIH) Office of Dietary Supplements, 2022), the UK population is known to be deficient (Lancet Diabetes and Endocrinology, Lancet Diabetes & Endocrinology, 2016) along with other developed countries including Australia, New Zealand and parts of Europe (Andersson et al., 2012). Many countries now legislate for salt to be iodised in order to boost population intake, which does not occur in the UK and has caused criticism in mis-messaging that encourages additional salt consumption (Smyth, 2021).

Where seaweed consumption is higher, health benefits beyond iodine sufficiency have been observed: Japanese women consume 200 times as much iodine per day as those in the US and experience reduced rates of breast cancer (Fleurence & Levine, 2016) with the iodine being believed to act as an antioxidant to reduce tumours (Brown et al., 2014). Iodine's role in therapeutic radiotherapy has also led to suggestions that the relatively high iodine levels in residents near the Fukushima nuclear disaster may have ameliorated some of the effects of nuclear poisoning (Smyth, 2021).

Many species of seaweed have been noted as a particularly good source of iodine owing to bio accumulation processes that concentrate the iodine from seawater within the algae (Smyth, 2021). A comprehensive review of the UK seaweed market by Redway & Combet, 2023, however, has highlighted the large variability in iodine content of different seaweed products and a need for increased labelling of iodine levels to enable informed consumer choices (Redway & Combet, 2023). The same review also makes recommendations on processing practices to lower iodine content to ensure food safety, such as boiling, soaking, washing or dehydration (Redway & Combet, 2023).

A better understanding of the levels of iodine contained in seaweed and its impact is needed: some species can accumulate it to high levels that may need to be declared on food products (Barbier et al., 2019): market appraisal of seaweed products in the UK revealed a median iodine content per serving of 400 µg (Redway & Combet, 2023) when 600 µg per day is the recommended upper limit for UK adults (Bath & Pettitt, 2022). Concentration, bio availability and absorption will also be affected by processing (e.g. drying or cooking), the food matrix and the impact of any other foods that are eaten along side it (Smyth, 2021). High iodine concentrations in the body are regulated through the Wolff–Chaikoff effect, so occasional consumption of seaweeds with higher quantities of iodine should not pose high risk to healthy individuals and excesses can be safely excreted (Bürge, 2010).

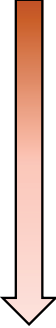
Considering these aspects, in addition to the historical and continued prevalence of seaweed in Asian diets, it is likely that moderate consumption of seaweed in British diets can be assumed safe.

**Table 6.** The significant micronutrient potential of a portion of European seaweed.

		Average % contribution of 5 g portion of dry seaweed to recommended daily allowance											
	Species	Ca	Cu	Fe	I	K	Mg	Mn	Mo	Na	P	Se	Zn
Green macroalgae	<i>Ulva</i> spp.	3.75	5.63	48.75	164.38	5.00	30.63	30.63	No data	4.38	1.88	5.63	1.25
Red macroalgae	<i>C. crispus</i>	11.25	1.63	6.88	2013.13	5.63	8.75	45.00	3.75	6.88	1.88	5.63	5.63
	<i>Gracilaria</i> spp.	1.88	3.75	23.13	156.88	17.50	4.38	57.50	1.88	3.13	1.25	9.38	4.38
	<i>P. calcareum</i>	189.38	6.88	No data	113.13	0.63	No data	43.75	No data	No data	No data	No data	0.75
	<i>P. palmata</i>	2.50	1.88	4.38	618.75	11.88	3.13	36.25	3.75	0.81	1.88	0.94	1.19
	<i>Porphyra</i> spp.	2.50	5.19	9.38	141.88	6.25	6.88	6.25	2.19	6.25	3.13	2.19	1.88
Brown macroalgae	<i>A. esculenta</i>	9.38	1.00	13.75	2062.50	6.25	10.63	3.13	6.88	9.38	2.50	5.00	1.50
	<i>A. nodosum</i>	6.88	9.38	7.50	3172.50	9.38	11.88	6.25	6.88	10.63	1.88	5.00	2.50
	<i>F. spiralis</i>	4.38	8.13	20.00	No data	8.13	9.38	21.25	No data	6.88	No data	1.81	13.75
	<i>F. vesiculosus</i>	7.50	9.38	11.88	1650.00	9.38	10.63	39.38	No data	9.38	1.88	5.00	2.50
	<i>H. elongate</i>	3.75	1.25	0.31	398.13	12.50	3.13	5.00	0.31	3.13	No data	No data	1.06
	<i>Laminaria</i> spp.	6.88	2.50	2.50	20.25	13.75	9.38	1.88	1.25	6.25	2.50	0.88	1.25
	<i>S. latissima</i>	6.25	1.25	8.13	9.69	13.13	10.00	3.13	6.88	8.13	3.75	10.63	1.25
	<i>U. pinnatifida</i>	6.88	1.88	2.50	828.13	10.00	11.88	2.50	No data	10.63	No data	4.38	2.50

Adjusted from an evaluation by Circunsião et al. (2018).

**Table 7.** Purchase forms for seaweeds.

Purchase form	Cost to customer <sup>a</sup>	Storage conditions	Shelf life <sup>a</sup>	Availability	Comments
Fresh	Highest	Refrigerator	5 days	Low	Wet weight leads to high transport costs so generally only found at/near seashore markets. Highest flavour and nutritional content. Highest price point.
Frozen		Freezer	2+ years	Low	Extends shelf life but adds processing and transport costs.
Dried		Ambient, (packaged)	1+ years	Medium	Light weight and small dimensions for transport leads to lower costs and wider availability.
Cooked		Ambient (tinned)	5+ years	High	Can be found in tins in major UK supermarkets (Parson's Laverbread); available to order through Castell Howell wholesalers.
	Lowest				

Based on Blikra et al. (2021) with additional information from seaweed product producers (Parson's Pickles, 2024; Seaweed, 2024)<sup>a</sup>.

demand without turning to potentially damaging wild-harvesting cultivation, activity would therefore have to increase dramatically.

Table 7 summarizes the situation: these products are expensive for schools to acquire and use, costing as much as 50 p for every school meal. Given that the current budget is £2.90 per meal (Welsh Government, 2024b) this makes its use without recipe redesign and costing changes difficult.

Menu adaptation to take account for this is not unrealistic as seaweeds can be incorporated into the diet in several ways. Traditionally, they are consumed in small quantities regularly throughout the day, for example as a nori sushi wrap, sprinkled in miso soup (Clearspring, 2024) or combined with scrambled eggs (Williams, 2023). Western chefs have attempted to broaden their uses to suit ingredients outside Asia, utilizing the natural umami flavours that stem from high glutamic acid content (Mouritsen et al., 2012). This has a double benefit in that recipes reach a depth of flavour that is not otherwise possible without the additives and table salt that are often used to create this (Carrascal et al., 2016). Examples of less traditional seaweed recipes include inclusion in tacos (Lofoten Seaweed, 2024), baking into bread and incorporating into ice cream (Mouritsen et al., 2012) or pizza (Bouga & Combet, 2015).

## Discussion

Seaweed can provide significant quantities of specific micronutrients listed in the Welsh school meal requirements and its appropriate use would therefore enhance meal quality, particularly if used in place of typical flavour enhancers (fat, sugar and salt). It overcomes many challenges faced by caterers in terms of palatability and nutritional demands, whilst providing strong support for environmental and local sourcing metrics where UK options are used. Despite these clear benefits, there are restrictions to its current use owing to unavailability of suitable products and the cost implications of sourcing these.

Mechanisms to stimulate market demand to bring down costs may involve a push in two directions (Fig. 3): improving the desirability of seaweed as food (thus creating greater consumer buy-in) whilst supporting supply to caterers with suitable seaweed products in wholesaler procurement catalogues. Food wholesalers have an active and real opportunity to contribute to provision of sustainable food systems by expanding their offer to include seaweed as a raw ingredient or inclusion in pre-prepared items (e.g., sauces). The benefits seaweed can offer can be realized by compiling a playbook of culinary uses to suggest easy additions and swaps (e.g., as a salt replacement), along with more advanced flavour combinations that utilize the umami credentials of seaweeds. Examples may include traditional uses such as soup flavouring or more novel approaches such as providing a 'meaty' flavour to plant-based dishes or as a taco topping, as discussed above. A fuller understanding of the specific nutrients contained in UK seaweeds is needed for the true benefits to be adequately accounted for. This study considers only a modest 5 g dried portion as an



**Fig. 3.** Recommendations and main societal drivers to enable increased seaweed inclusion in school meals.

**Table 8.** Seaweed suppliers and costings in 2024.

Product	Price per 100 g	Consumed portion	Cost per portion
Dried UK seaweed <sup>a</sup>	N/A	–	–
Dried UK seaweed <sup>b</sup>	£10	5 g	£0.50
Cooked laverbread puree <sup>c</sup>	£1.70	25 g	£0.43
Cooked laverbread puree <sup>d</sup>	£1.67	25 g	£0.43

<sup>a</sup>(Bidfood, 2024; Celtic Foodservices, 2024; Harlech Foodservice, 2024; Howell, 2024); <sup>b</sup>(Car-y-Mor, 2024; The Cornish Seaweed Company, 2024; Pembrokeshire Beach Food Company, 2024); <sup>c</sup>(Parson's Pickles, 2024); <sup>d</sup>(Seaweed, 2024).

addition (rather than an alteration) and is limited to nutritional values for species listed on the official CoFID database (Tables 3 and 8); clarifying these figures for UK harvest and consumption conditions may indicate greater gains from alternative species.

The two-pronged approach described enables the considerable benefits of seaweed to be realized. With sensible catering use and a growing culinary demand reducing costs, the inclusion of seaweed in Welsh school meals could become a real possibility. Recommended actions are summarized in the graphical abstract and Fig. 3 with this researcher strongly encouraging more focus on local, sustainable sources of UK seaweed to maximize UK resilience.

When financial viability is reached, or nutritional wellbeing is seen as having greater economic worth, important benefits to childhood nutrition can then be attained. The addition of seaweed to school meals

represents Wales' Future Generations Act commitments for a healthier, prosperous and environmentally responsible Wales in making significant progress towards public health, heritage foods and supporting local livelihoods (National Assembly for Wales, 2015).

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Funding

This work was supported by the UK Food Systems Centre for Doctoral Training that is funded by the Transforming UK Food Systems Strategic Priorities Fund Programme managed by UKRI [grant number BB/V011391/1].

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