Seaweed in Food

Insights, Opportunities, and Industry Needs for the European Food Sector

2026

hogeschool vives

I3-4 SEAWEED

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Excecutive summary

This report serves as a practical guideline for food companies by bringing together key information needed to work with seaweed as an ingredient. A specific focus is placed on the use of **whole seaweed biomass**. Companies need **reliable information on raw material characteristics, functional performance, safety, and regulatory requirements** before seaweed can be integrated into scalable product development. To support this process, the report brings together current knowledge and industry-relevant insights in a structured and accessible format.

The report is structured to support food companies in understanding and applying seaweed in product development. It begins with an overview of the European seaweed market and the currently approved species for food applications. This is followed by a detailed assessment of the nutritional, functional, and sensory properties of seaweed relevant to food formulation. Subsequent sections address key regulatory and food safety considerations, including legal requirements, potential risks, and quality aspects. Building on these elements, the report then **identifies the main industrial needs and challenges** across the supply chain, highlighting both existing bottlenecks and areas for innovation.

By consolidating these perspectives, the report aims to **close existing knowledge gaps** and provide an **industry-oriented framework** for evaluating seaweed ingredients and selecting suitable raw materials based on application requirements, quality attributes, functionality, safety, and regulatory compliance. In doing so, it seeks to **reduce uncertainties** associated with seaweed adoption, support **informed product development decisions**, and facilitate the transition from initial interest to feasible, scalable, and commercially relevant food applications.

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1. Introduction to seaweed as a food ingredient

Seaweed has long been a staple in Asian diets but has only more recently gained attention in Western food systems. This shift is driven by increasing consumer demand for sustainable, plant-based, and functional ingredients that support both health and environmental objectives (Cherry et al., 2019; Bouga & Combet, 2015). Globally, there are more than 10,000 described seaweed species, which are broadly classified into three main groups: red algae (*Rhodophyta*), brown algae (*Phaeophyceae*), and green algae (*Chlorophyta*). However, only a limited selection of these species is currently permitted for food use in the EU due to regulatory and safety considerations.

In Western markets, the use of seaweed has historically been dominated by extracts and derivatives such as agar, carrageenan, and alginates. These hydrocolloids are well established in industrial food production due to their reliable **gelling, thickening, and stabilising properties**, and are widely applied in products such as **dairy alternatives, desserts, sauces, and processed meats** (Holdt & Kraan, 2011).

More recently, the use of **whole seaweed biomass** has started to emerge. Incorporated as dried, powdered, or fresh ingredients, whole seaweed can contribute to **nutritional enrichment** by providing dietary fibres, vitamins (including vitamin B12), and antioxidants. It also introduces **distinctive sensory characteristics** such as umami and saltiness. Currently, 37 seaweed species are classified as non-novel foods in Europe, each with distinct compositional and functional characteristics. This diversity makes seaweed an attractive ingredient for **product innovation and differentiation**, while facilitating its broader use in food product development. In addition, it can offer opportunities for **clean label positioning and sustainability-driven product development**. Consequently, seaweeds re increasingly being explored in applications such as snacks, bakery products, pasta, condiments, and plant-based meat alternatives (Penalver et al., 2020)

However, several challenges still limit wider adoption, including flavour acceptance, supply chain consistency, regulatory complexity, and limited consumer familiarity in Europe (Bouga & Combet, 2015). To address these challenges, this **report provides a concise and practical assessment of seaweed as a food ingredient**, with a specific **focus on whole biomass applications** from non-novel species currently permitted on the European market. Although still underexplored, whole seaweed biomass offers important economic, nutritional, and sustainability advantages.

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2. The European Seaweed Market: Data & Trends

With a globally raising population and demand for food, there is an increased need for alternative food sources. Because of their nutritional profile and potential more sustainable source of high-value bioactive compounds, seaweed has gained major interests. Along the European coast, seaweed has been harvested for human consumption for several centuries as it played a significant role in supplements and medicines, fertilizer and feed (Mendes et al., 2022).

The seaweed production in Europe is still negligible compared to Asia**.** Asia dominates the sector, producing **99% of global marketed seaweed**, amounting to **34.7 million tonnes annually** valued at **USD 14.85 billion**, while Europe's industry with a production volume of only **0.8%** remains small and largely driven by start-ups. In addition, the European algae consumption is expected to be significantly lower than Asian countries where the algae consumption is around 2 kg per capita^{-1} year^{-1} (Fricke A, 2024; Jueterbock et al., 2025; Mendes et al., 2022). However, 1.34% of the new European foods and drinks launched in 2017 were traditional products, such as cookies, pasta, bread with algae ingredients. In 2018, meat substitutes such as burgers and grills with algae accounted for EUR 1.82 million in Europe (Mendes et al., 2022). The current European macroalgae market size is estimated to be 2.3 USD Billion and is expected to grow to a value of **4.2 USD Billion in 2035** (FMI, 2025). By 2030, the European Commission aims to increase production to **8 million tons**, valued at 9 billion Euros, and potentially creating 85,000 jobs (Vincent et al., 2020).

The largest European application of seaweed biomass is for food (36%) and food-related purposes (15%). Besides that, macroalgae are produced for cosmetics and well-being products (17%), feed (15%), and others (22%) like biofuel and fertilizers. Due to increased development and innovation in the seaweed production together with a higher demand for eco-friendly food products, the European algae market is developing fast (Araújo et al., 2021; Kuech et al., 2023; Mendes et al., 2022). As the sector continues to expand, food companies looking to incorporate seaweed into their products may face challenges in identifying suitable suppliers and partners**. Several databases and online platforms** can support companies in finding seaweed producers, processors, relevant knowledge institutions and other stakeholders, both internationally and within Europe:

The **Phyconomy database** – founded by Steven Hermans – currently contains extensive information about more than 1400 global organizations in the global seaweed industry and tracks investments in the seaweed economy.

[Phyconomy database]

For stakeholders interested in European seaweed companies, **the PhyCo Seaweed and Companies Explorer** provides an overview of businesses active across the seaweed value chain. Developed by ULPGC within the I3-4 Seaweed project, this B2B web tool maps companies involved in cultivation, processing, biotechnology, food, cosmetics, agriculture, and other algae-related applications. Users can search and filter companies by seaweed species or company name.

[PhyCo Seaweed and Companies Explorer]

Blue Biomatch Algae Working group is an online community and forum for everyone working with alga. It compromises experts and enthusiasts from all fields of algae innovation, including policy makers, product developers, cultivators, LCA experts, biodiversity researchers. It aims to maximise cross-disciplinary collaboration and broad stakeholder engagement in initiatives across Europe (and beyond).

[BlueBioMatch]

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3. EU-approved seaweed species for food use

Not all seaweed species consumed elsewhere in the world are permitted for commercial food use in the EU. Under EU legislation, a **novel food** is defined as food that had not been consumed to a significant degree by humans in the EU before 15 May 1997, when the first Regulation on novel food came into force. A novel food needs to undergo a pre-market authorization before it's allowed to be placed on the EU market (European commission). As of May 2026, 37 algae species are recognised as non-novel, which is expected to facilitate their use in food applications by avoiding the time and costs associated with novel food approval (Table 1). The **EU Novel Food Catalogue remains** the most up-to-date reference source for verifying the regulatory status of individual seaweed species.

EU Novel Food Catalogue

Table 1: Non-novel seaweed species categorised in green, red and brown algae species (European Commission, 2026)

	Common name	Latin name
Green algae	Sea Lettuce	*Ulva Lactuca Linnaeus*
	Gut Weed, Green bait weed and Grass kelp	*Ulva intestinalis*
Red algae	Irish Moss, Carrageen	*Chondrus crispus*
	Lacy Red Weed	*Erythroglossum laciniatum*
	Agar Weed	*Gelidium amansii*
	Agar Seaweed	*Gelidium corneum*
	Agarophyte	*Gracilariopsis longissima*
	Nori	*Neopyropia leucosticta*
	Nori, Purple Laver	*Pyropia tenera*
	Dulse, Dillisk, Palmwier	*Palmaria palmata*
	Maerl	*Phymatolithon calcareum*
	Laver	*Porphyra dioica*
	Purple Laver	*Porphyra purpurea*
	Nori, Laverbread	*Porphyra umbilicalis*
	Nori	*Pyropia yezoensis*
		Alsidium helminthochorton
	Coral Weed	*Corallina officinalis*
		Eucheuma denticulatum
		Eucheuma horridum
		Gracilaria gracilis
	Irish moss, Clumps or turf	*Mastocarpus stellatus*
Brown algae	Winged Kelp, Dabberlocks, atlantic wakame	*Alaria esculenta*
	Knotted Wrack, Egg Wrack, rockweed, knotswier	*Ascophyllum nodosum*
	Arame	*Eisenia bicyclis*
	Toothed Wrack	*Fucus serratus*
	Spiral Wrack	*Fucus spiralis*
	Bladder Wrack, blaaswier	*Fucus vesiculosus*
	Sea Spaghetti	*Himanthalia elongata*
	Oarweed, vingerwier	*Laminaria digitata*
	Tangle Kelp	*Laminaria hyperborea*
	Kombu	*Saccharina japonica*
	Sugar Kelp, royal kombu	*Saccharina latissima*
	Hijiki, Black Seaweed	*Sargassum fusiforme*
	Wakame	*Undaria pinnatifida*
	Southern bull kelp	*Durvillaea antarctica*
		Ecklonia cava
	Giant kelp	*Macrocystis pyrifera*

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4. The potential of Seaweed as a nutritional, functional and sensory food ingredient

Seaweeds are increasingly recognised as sustainable, natural sources of macro- and micronutrients, alongside a wide array of bioactive compounds, making them attractive candidates for innovative food applications. They are broadly classified into **green**, **red**, and **brown** seaweeds, each characterised by distinct photosynthetic pigments, and possess different nutritional composition, techno-functional behaviour, and sensory properties (Mendes, 2022). Because these biological differences shape their relevance in food formulation, the following section provides an overview of the **nutritional**, **functional**, and **sensorial** characteristics of whole seaweed biomass, structured according to seaweed type. The following section will explore how these characteristics can be used in food product development and provide an indication of which types of seaweed are most suitable for specific uses such as nutrient enrichment, textural modification, colour enhancement, or flavour profiling, highlighting their potential as versatile ingredients in innovative and sustainable food products.

To date, the food industry has relied predominantly on **seaweed extracts**, particularly phycocolloids such as agar, carrageenan, and alginate, which are widely used to improve texture and stability in processed foods. Although extracts are providing a consistent quality, the use of **whole seaweed biomass** is gaining attention due to its additional health-promoting components and its alignment with clean-label and sustainability goals. Unlike extracts, whole seaweed does not require E-number labelling, undergoes fewer processing steps, offers lower production costs, and reduced environmental impact (Bennett, 2023; Hardouin, 2014; Torres, 2020; Rioux, 2017).

A comparison between seaweed extracts and whole biomass is summarised in Table 2, highlighting key differences in labelling, processing, costs, and sustainability performance. These distinctions underline why whole seaweed is becoming an increasingly relevant ingredient for product developers seeking natural, minimally processed, and environmentally responsible solutions.

Table 2: Comparison between seaweed extracts versus the use of their whole biomass

	Seaweed extracts	Seaweed biomass
Label	E-number	No E-number because it is used as an ingredient
Processing steps	Washing → stabilization → extraction → purification	Washing → stabilization → grinding
Production costs	High	Low
Sustainability	Bypass flows, high energy	No bypass flows, low energy

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4.1 Nutritional properties of seaweed

In the following sections, selected macro- and micronutrients available in seaweed are discussed in greater detail. Nutritional fact sheets for some of the most commonly used seaweed species, as documented by CEVA, can be found in the Annex I.

4.1.1 Proteins and amino acid profile

Seaweed is a promising and valuable source of protein, with a slightly higher quality than most other plant-based sources as they contain substantial levels of essential amino acids which can account for nearly half of the total amino-acid content. However, tryptophan and lysine are generally limiting in most algal species, and cysteine is often present at very low levels or remains undetectable. The total protein content depends on the species, with red algae containing the highest amount (10-47% DW), followed by green (8-30% DW) and brown (5-20% DW). The amount of protein is also depending on the geographical location and seasonal and environmental factors (Healy, 2023; Salido, 2024; Pereira et al., 2024).

4.1.2 Lipids

Macroalgae contain in general a low level of lipids (0,3-4,8%) but have a relatively high proportion of ω-poly-unsaturated fatty acids (PUFAs), especially EPA, which provide proven health benefits. The lipid content also depends on the environmental and cultivation conditions with cold causing a higher lipid level (Øverland, 2018; Salido, 2024).

4.1.3 Vitamins & minerals

Vitamins are well represented in macroalgae with both water-soluble vitamins such as B1, B2, B12 and C and fat-soluble vitamins A, D, E and K found (Park, 2023). Especially the presence of vitamin B12 is important as people who are vegetarian or vegan often lack this vitamin. The highest vitamin B12 content has been found in the red algae Dulse and Nori (Martínez-Hernández, 2018).
The levels of minerals such as calcium, magnesium, iron, iodine, copper, manganese, phosphorous, zinc and selenium are generally high in seaweeds, but little is known about bioavailability. As seaweeds contain less phytates that can bind with iron, unlike many grains and legumes, the mineral is better absorbed. Both the vitamins and minerals content can vary depending on the batch, growth condition and seasonality (Øverland, 2018; Healy, 2023).

4.1.4 Fibres

Growing interest in the health benefits of dietary fibre has encouraged the search for sustainable alternative sources. Seaweed, known for its naturally high fibre content, is considered a promising candidate. Total insoluble fibre contents in seaweed typically range from 33 to 50 g/100 g DW (Dawczynski et al., 2007). The type of carbohydrate found in algae depends on the species, but also the season and cultivation conditions (Salido, 2024).

4.1.5 Antioxidative properties

Besides the high content of dietary fibres, vitamins and proteins, seaweed is also rich in other bioactive compounds such as polyphenols, carotenoids, tannins, peptides, lipids, enzymes, vitamins and terpenoids (GUO, 2022; Holdt & Kraan, 2011) (Table 3). For example, Kaur et al. found that *Porphyra spp*. (Nori) has great potential in improving the nutritional profile of food products (Kaur, 2025).

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Table 3: Antioxidants in the different seaweed groups

	Antioxidant
Green algae	Carotenoids (e.g. β-carotene, lutein) chlorophyll-related antioxidants, vitamin C, tocopherols
Red algae	Phycobiliproteins (phycoerythrin, phycocyanin derivatives), carotenoids (e.g. β-carotene, lutein), vitamin C, polyphenols
Brown algae	Phenolic compounds (especially phlorotannins) and carotenoids (e.g. fucoxanthin)

4.1.6 Salt

As seaweed is naturally high in salty taste, they can be used as salt substitute. Their Na/K ratios are generally low (<1), meaning that they are better for your cardiovascular health than the conventional salt (NaCl) on the market. However, these ratios vary in between species so not every single seaweed is an equally good salt replacer. An example of a good salt replacer would be *Palmaria palmata* (Dulse), *Laminaria digitata* or *Himanthalia elongata* (Cardoso et al., 2015; Healy, 2023).

4.1.7 Food and health claims

Seaweeds contain meaningful levels of key macro- and micronutrients and can therefore help food products meet the requirements for several EU-permitted nutrition claims, including “source of iron”, “source of fibre”, “source of protein” and “source of vitamin B12” (Cherry et al., 2019). Within the European Union, these nutrition claims must comply with (Regulation (EC) No 1924/2006), which sets the general rules for how nutrition and health information may be communicated on food labels. It is important to distinguish these claims from health claims. Health claims often refer to food claims as a requirement, but are related to a nutrient’s role in growth, development, or physiological function; require robust scientific substantiation and must undergo evaluation by the European Food Safety Authority (EFSA).

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4.2 Techno-functional properties of seaweed

4.2.1 Phycocolloids

Phycocolloids form a distinct class of high-molecular-weight carbohydrates naturally present in different seaweed groups (red, brown and green), each producing specific types of hydrocolloids (Table 4). Phycocolloids such as alginate, carrageenan, and agar have been used for decades in the food and beverage industry to improve texture and sensory quality and are well established as safe ingredients. These seaweed-derived hydrocolloids function primarily as gelling, thickening, emulsifying, and stabilizing agents and are increasingly applied as fat replacers due to their ability to mimic fat-like mouthfeel. Their long-standing commercial relevance is linked to their strong functional properties and broad compatibility with industrial food processing (Cherry et al., 2019).

Table 4: Phycocolloids present in the different seaweed groups (Häder et al., 2020)

Green seaweed	Ulvan
	Lignin
	Xyloglucan
	Xylopyranose
	(Hemi)cellulose
Red seaweed	Carrageenan
	Agar
	Xylan
	Agaropectin
	Porphyran
	Floridean starch
	Cellulose
	Funoran
Brown seaweed	Alginate
	Mannitol
	Laminarin
	Fucoidan
	Cellulose
	Fucoidan

It is important to note that, although whole seaweed biomass still exhibits a range of techno-functional properties driven by its native phycocolloids, the resulting functionality reflects the combined contribution of these polymers together with dietary fibres, minerals, and other cell-wall components that remain intact within the macroalgal matrix. An overview of key seaweed species, their derived phycocolloids, and main applications is provided in Table 5 (Dawczynski et al., 2007; Domínguez, 2013; Häder et al., 2020; Rogel-Castillo, 2023).

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Table 5: Common use applications of different phycocolloids present in different seaweed groups and respective species

Green seaweed	
Name	**Techno-functional properties**
Ulva Lactuca (Sea Lettuce)	Contains ulvan, which can be used as a stabilizing agent in emulsions, making it applicable in formulations of milk and body creams in the food and cosmetic sectors (Morelli et al., 2019)

Red seaweed	
Name	**Techno-functional properties**
Chondrus crispus (Irish moss)	Produces large amounts of carrageenan's (up to 60% DW) and so is used as thickening, gelling and stabilizing agent. Carrageenan is a widespread ingredient in the dairy industry for example as a fat replacer in low-fat dairy products or stabilizer in ice cream (Hardouin, 2023)
Porphyra spp. (Nori)	*Porphyra sp*. is a pore source of carrageenan but other polysaccharides (porphyrin) were found to have good gelation properties (Ji, 2025). Beyond sushi, Nori is used in snacks and in fermented sauces (Kaur, 2025).

Brown seaweed	
Name	**Techno-functional properties**
Ascophyllum nodosum (Rock weed)	Main source for alginate extraction. This is used for gelling, thickening, stabilizing and emulsifying food products and has a good water holding capacity. Alginate is incorporated in e.g., meat and fish analogues, plant-based dairy alternatives, (gluten-free) baked goods, or as egg replacement besides the commonly used food products such as ice cream, sauces & dressings and restructured food (Hasnain, 2020; Hefft, 2024).
Laminaria hyperborea (Forest kelp)	
Laminaria digitata (Oarweed)	
Alaria esculenta (Atlantic wakame)	These are the predominant species in Europe for alginate extraction though they have a lower alginate content than *Laminaria spp. (*Liberg Krook, 2025). These species are also more eaten as a whole ingredient but can also be used as e.g., fat replacer (Ilyas, 2023).
Saccharina latissimi (Sugar kelp / Royal kombu)	
Himanthalia elongata (Sea spaghetti)	
Undaria pinnatifida (Wakame)	Globally eaten as a whole ingredient (Shuang, 2023).

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4.2.2 Pigments

Seaweeds contain a broad array of natural pigments that contribute to colour and mild bioactive properties when incorporated into foods. The main pigment groups include **chlorophylls**, **carotenoids**, and **xanthophylls**, although the type and concentration of these pigments vary widely between species. Red seaweeds additionally contain water-soluble **phycobiliproteins**, which provide pink, red, or purple hues (Table 6) (Aryee et al., 2018; Aymerich et al., 2022).

Table 6: Pigments in the different seaweed groups

	Pigment
Green algae	Chlorophyll a and b
Red algae	Chlorophyll a
	Phycobiliproteins (phycocyanobiline, phycoerythrobiline, phycourobiline, phycobilivioline)
Brown algae	Chlorophyll a and c
	Xanthophylls (carotenoiden) f.e. Fucoxanthin

When used in food applications, seaweed pigments can produce a wide range of colours depending on the species. Green and brown seaweeds typically yield **green to olive-brown tones** due to chlorophylls and fucoxanthin, while red seaweeds introduce **pink, red, or purple hues** through their phycobiliproteins. When **whole seaweed biomass** is incorporated, this full pigment mix is retained, resulting in natural but **non-standardised colour profiles** that vary with species, season, harvest conditions, and processing. In some applications, such as plant-based meat analogues, his natural colour evolution is desirable, for example when a red, "raw-like" appearance turns brown during heating (Wu et al., 2024; Lee et al., 2025). However, the colouring capacity of whole seaweed is often limited in practice because of several reasons. Firstly, grinding seaweeds into a fine, uniformly dispersible flour is technically challenging, and commercially used forms typically consist of flakes or coarse powders. Consequently, whole seaweeds tend to create visible speckles rather than evenly distributed colour throughout the product. Moreover, inclusion levels are often restricted to a few percent due to the characteristic marine flavour and aroma, which can dominate depending on the desired sensory profile of the final food product. In addition, pigments are also sensitive to processing: phycobiliproteins from red seaweeds are highly heat-labile, and chlorophylls readily degrade under heat or low-pH conditions (Aryee et al., 2018; Aymerich et al., 2022).

Figure 1: Impact of milling size on visual colour distribution in seaweed enriched pasta

When seaweed is incorporated into food as whole biomass, its pigments are regarded as intrinsic components of a food ingredient rather than as added colourants. Consequently, the colour imparted by seaweed is generally considered a **colouring foodstuff**, and no separate authorisation is required provided that the seaweed species itself is approved for human consumption. This allows whole seaweeds to naturally impart green, brown, or red hues to food products without falling under EU food additive legislation, making them attractive ingredients for clean-label formulations (European Commission, 2011; Vieira et al., 2025 In contrast, the use of purified or extracted seaweed pigments as food colourants is subject to stricter regulatory requirements. Within the European Union, only a limited number of seaweed-derived pigments are authorised as food colour additives under Regulation (EC) No 1333/2008, with chlorophylls and chlorophyllins (E140) and their copper complexes (E141) representing the principal approved pigments (European Commission, 2011).

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4.3 Sensory properties of seaweed

Table 7 shows some characteristic sensory properties of several seaweeds most commonly used in the food sector (Dahlstedt, 2025; Figueroa et al., 2022; Francezon, 2021). Note that these sensory properties may vary based on the origin, batch and seasonality.

Table 7: Sensorial properties of different seaweed groups and species

Green seaweed	
Name	**Sensory properties**
Ulva Lactuca (Sea Lettuce)	Strong flavour described as ocean, salty, similar to sorrel, mouldy/earthy. Slightly bitter taste that can worsen by drying. Thin, semi-transparent and soft flaky texture.

Red seaweed	
Name	**Sensory properties**
Palmaria palmata (Dulse)	Crunchy, tough and chewy texture. It has an umami, salty, and sweet taste, and hay, dried fish, slightly iodized flavour with a strong marine aroma. When dried, it develops notes of liquorice and smoke. When toasted it gets a nutty flavour and can have a bacon-like flavour when fried.
Chondrus crispus (Irish moss)	Generally it has a neutral or barely perceptible taste but can have a mild sea-like, crustacean, nutty and salty flavour.
Porphyra spp. (Nori)	Fine and cartilaginous texture. Tastes sweet, salty umami of dried mushrooms and bitter with mineral flavour. It smells like the ocean, but also earthy and herbal.

4.4 Consumer acceptation and perception

Although seaweeds are widely consumed in many Asian countries, they remain a largely underutilized food source in Western diets. Growing interest in Europe highlights their potential both as primary food ingredients and as functional components. Yet, consumer adoption is still limited, and one of the key barriers is food neophobia, the hesitation or reluctance to try unfamiliar foods. This plays an important role alongside practical challenges related to food safety, quality preservation, and product optimization (Blikra et al., 2021).

Eurobarometer 2024 data (Figure 1) shows that seaweed is familiar to many Europeans but remains underutilized. Its most successful application is in sushi rolls, consumed by 41% of EU27 respondents, yet adoption drops sharply across other formats such as salads (20%), snacks and supplements (18%), and plant-based substitutes (8%). Notably, 22% of Europeans have never tried seaweed at all, while only 13% recognize consuming seaweed-derived ingredients like carrageenan in everyday products such as yoghurt or ice cream, revealing that seaweed is already widespread in the food system but largely invisible to consumers.

On the motivational side, taste (47%) and health benefits (35%) are the primary drivers of consumption, while environmental values play a surprisingly minor role (15%). The biggest barrier is simply habit: 54% of infrequent consumers are just not used to eating these products, suggesting that the core challenge is familiarity rather than active rejection. Belgian consumers additionally flag price as a notable obstacle (19% vs. 13% EU27). This suggests that the key opportunity lies not in overcoming aversion, but in making seaweed more visible, accessible, and integrated into everyday eating habits. Overall, the data suggests that the main barrier to increasing seaweed consumption is not taste or health perception, but rather a lack of familiarity and routine use. This points to a challenge, and at the same time an opportunity, that is more related to marketing and accessibility than to the product itself (Eurobarometer, 2024).

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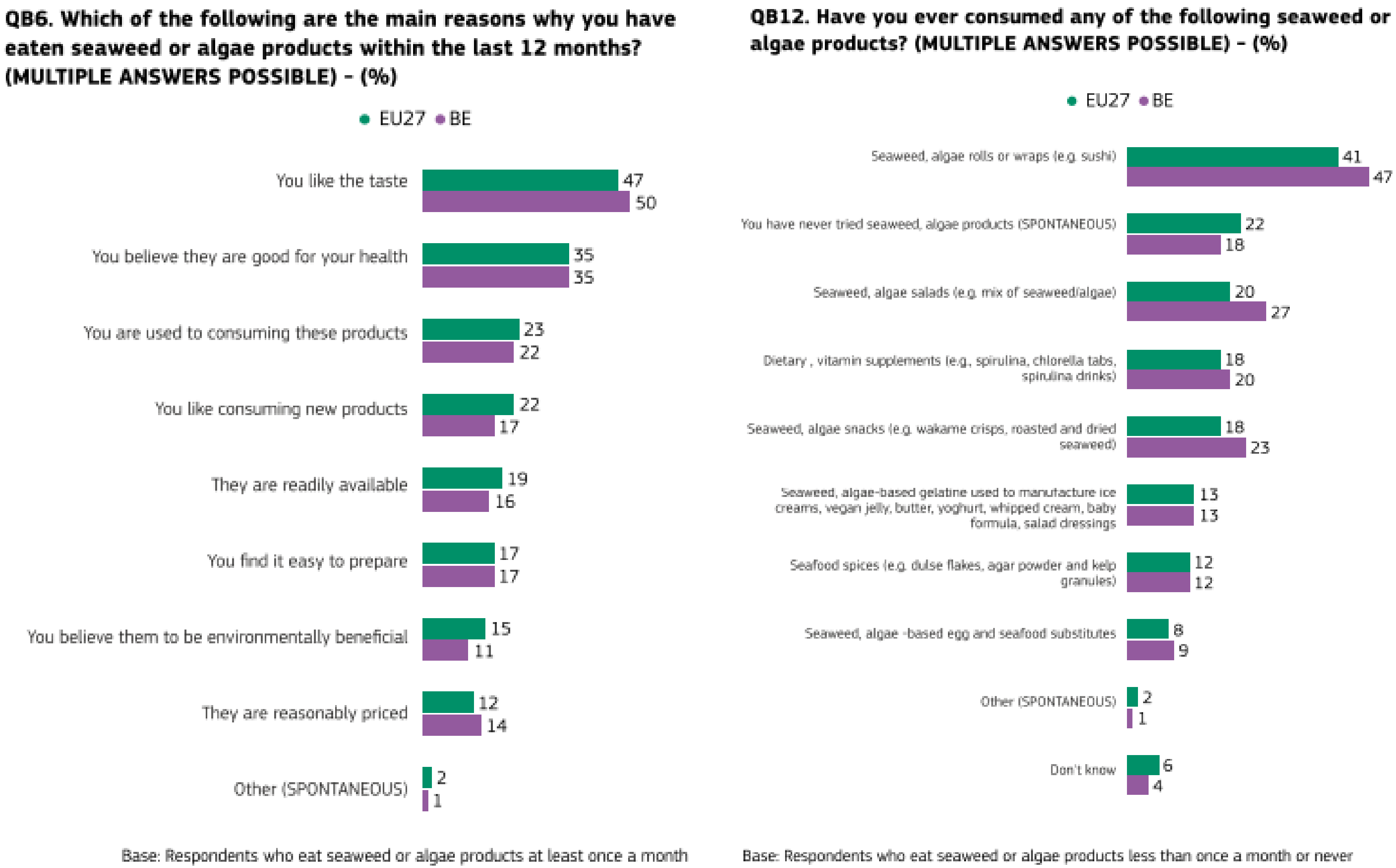
Figure 2: EU 27 Consumer habits regarding fishery and aquaculture products (2024)



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5. Legislation and food safety

5.1 Overview European legislation

An overview of European food safety legislation relating to the use of macroalgae can be found at **LexSeaweed,** a European Macroalgae Legislation Hub. This digital tool helps explore comprehensive EU legislation related to macroalgae cultivation, food safety, feed, bio stimulants, cosmetics, trade and environmental regulation with semantic search by genus, species, compound and legal theme.

LexSeaweed

5.2 Allergens

Current evidence indicates that edible algae may contain proteins with allergenic potential; however, the prevalence and clinical relevance of these allergens in the general population remain unclear. Various proteinaceous allergens have been identified in algal food sources and are listed in the Allergome database (Allergome), although several of these proteins have not yet been fully biochemically characterised. Reported allergic reactions associated with edible algae are relatively limited and include symptoms ranging from mild cutaneous and gastrointestinal manifestations to, in rare cases, more severe reactions. It should also be noted that some allergenic proteins identified in algae may belong to broader groups of marine allergens that are not unique to algal species. Further research is therefore warranted to better characterise these proteins, assess their clinical significance, and improve understanding of potential risks for sensitive individuals. Such information would support clinicians, industry stakeholders, regulators, and consumers in making informed decisions regarding the safe use of edible algae (James et al., 2023; Mildenberger et al., 2025).

5.3 Iodine and Heavy metals

Seaweed's ability to absorb minerals from seawater is both its greatest asset and fundamental vulnerability. **Macroalgae concentrate beneficial nutrients like iodine, calcium, and magnesium.**

Seaweeds are among the richest natural sources of iodine, an essential micronutrient required for the synthesis of thyroid hormones and the maintenance of normal thyroid function. Historically, inadequate iodine intake has been a major public health concern, leading to iodine deficiency disorders such as goitre, impaired cognitive development, and hypothyroidism. Owing to their high iodine content, seaweeds can serve as an effective dietary source of this nutrient and may contribute to improving iodine status in populations at risk of deficiency. However, the iodine concentration of seaweeds varies considerably among species, and excessive consumption may result in iodine intakes that exceed recommended levels, potentially increasing the risk of thyroid dysfunction, including hyperthyroidism. Therefore, while seaweed offers significant potential as a natural strategy to address iodine deficiency, its incorporation into foods and diets should be carefully managed to ensure safe iodine intake (Healy et al., 2023).

The recommended intake of **iodine** issued by EFSA for adults and children older than 10 years is **150 µg/day**. Intake above 600 µg/day however is not recommended (Hogstad et al., 2023). EFSA (2006) concluded that the ingestion of iodine-rich algal derived food products, particularly dried products, can potentially lead to dangerously excessive iodine intakes, if such products contain more than 20 mg iodine/kg dry matter and the exposed population lives in an area of endemic iodine deficiency (high risk subgroups are pregnant woman, children and individuals with thyroid dysfunction) (Mendes, 2022**). Brown seaweeds** are the species that have the highest concentrations which can exceed 10 mg/g dry weight, followed by red seaweeds (<1 mg/g dry weight) and green seaweeds (<0,1 mg/g dry weight) (CEVA, 2019).

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Unfortunately, seaweed can also **accumulate heavy metals** present in coastal waters: arsenic, cadmium, lead, mercury, and nickel. When industrial runoff or agricultural pollution affects coastal environments, seaweed becomes a repository for contaminants (Healy, 2023). Table 8 provides an overview of the maximum levels of heavy metals allowed in seaweed, as defined by the French Food Authority (CEVA, 2025).

Table 8: Maximum levels of inorganic compounds in algae (CEVA, 2025)

Parameter	Algae (vegetables or condiments) *mg/kg (DW)*
Inorganic Arsenic (As)	3
Cadmium (Cd)	0.5
Mercury (Hg)	0.1
Lead (Pb)	5
Tin (Sn)	5
Iodine (I)	2000

In the case of cadmium, a recent opinion from French ANSES on the maximum cadmium content for seaweed intended for human consumption recommends "a maximum cadmium concentration in seaweed that is as low as possible" due to the high exposure of the general population to this ubiquitous element (ANSES 2020).

These inorganic compounds can, in some cases, have **important implications** for recommended **inclusion levels** in product development, which need to be carefully balanced against the estimated daily consumption of the final product. This may also create constraints in relation to desired **nutritional positioning or food claims**, where higher inclusion levels are often required. It should however be noted that certain post-harvest processing steps, such as blanching, can help reduce iodine content, although the extent of reduction is variable and process dependent.

5.4 Pesticides

Although seaweeds may be exposed to pesticide residues through contaminated coastal waters, pesticides are generally considered a less significant food safety concern than iodine accumulation and the uptake of heavy metals. Nevertheless, the capacity of seaweeds to absorb environmental contaminants highlights the importance of appropriate site selection, monitoring, and regulatory control to ensure the safety of seaweed-derived food products (Azevedo, 2026).

Concerning **pesticide** residues, EC regulation 396/2005 sets maximum limits that must not be exceeded. The maximum limits applicable to algae and prokaryotic organisms are available in the appendix to the regulation or in the European Commission database and are set between 0.01 mg/kg and 0.1 mg/kg for a large number of pesticides.

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5.5 Microbiological food safety

Although no specific microbiological criteria for algae have been established at the European level, historical French recommendations for the microbiological quality of packaged dried algae are available and summarized in Table 9 (CEVA, 2025).

Table 9: Historical microbiological criteria for dried algae (CEVA, 2025)

Microbiological Parameter	Limit
Mesophilic aerobic germs	≤ 10^5 / gram
Faecal coliforms	≤ 10 / gram
Anaerobic sulfito-reducing bacteria	≤ 10^2 / gram
Staphylococcus aureus	≤ 10^2 / gram
Clostridium perfringens	≤ 1 / gram
Salmonella	Absence in 25 grams

Furthermore, a hazard analysis conducted as part of the HACCP study may identify the need to monitor additional microorganisms that could pose a risk to human health. CEVA (2025) also notes that the recommended criterion for *Clostridium perfringens* appears particularly stringent. In many food categories, substantially higher limits are accepted (up to 10^5/g for certain products), and ANSES currently considers this parameter more appropriate as a process hygiene criterion rather than a finished product safety criterion (CEVA, 2025). In practice, companies should therefore also assess microbiological criteria applicable to the specific food product category and consult national regulations or guidance in their country, as these may define more relevant limits for finished products.

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5.6 Packaging and storage

5.6.1 Seaweed packaging and storage

Conventional conservation techniques are drying, freezing and salting. For stable storage, seaweed is recommended to be **dried** to a moisture content of 8–12%. Dried seaweed is hygroscopic (absorbs moisture) and can be prone to lipid oxidation (especially in brown algae), pigment and vitamin degradation.

Dried seaweed is ideally vacuum-sealed and stored in a dark cool environment as the presence of oxygen and light can respectively lead to rancidity (PUFAs oxidation) and pigment loss. Oxygen absorbers are sometimes added. Packaging should contain moisture- and oxygen-barrier film (e.g., metallized PET, aluminium-laminated films, or multilayer plastics with EVOH). If properly dried and packaged in barrier films at ambient temperature, dried seaweed can last 12–24 months (Harrysson et al., 2021). An alternative for drying, as this method causes the seaweed to lose their original characteristics, would be **Modified Atmosphere Packaging (MAP)**. This conservation technique might be interesting as it is able to inhibit the respiration rate of minimally processed seaweeds, also preserving their colour and texture (Moreira-Leite et al.,2023).

5.6.2 Labelling

In the United States, the European Union, and other countries, labelling of all ingredients, including major allergenic sources, is required. In the European Union 14 major allergens are outlined by Annex II of the 'Council Regulation (EU) No.1169/2011. Similarly, in the US eight major allergens are currently recognised under Food Allergen Labelling and Consumer Protection Act (FALCPA) (2004). Currently, **no such requirement is needed for algal based components** and no studies were identified that addressed labelling of algal products or ingredients. However, it is worth noting that the novel food status of different algae species to be potentially used as food and food supplements, subject to the pre-market authorisation requirements of the 'Council Regulation (EU) 2015/2283 on novel foods' (2015) before they can be freely placed in the European market (James et al., 2023).

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6. Industrial needs and challenges for the Seaweed Food Industry

6.1 Seaweed Food Supply Chain

Figure 3 provides an overview of the European seaweed food-product supply chain, covering cultivation, processing, food production, and consumer acceptance. Across these stages, key challenges—such as limited and variable supply, food safety risks, lack of standardized quality, and low consumer familiarity—highlight the main industry needs for scaling the sector.
These include:

(i) Increased and reliable biomass production,
(ii) Validated processing and preservation strategies,
(iii) Consistent ingredient specifications for product development, and
(iv) Improved consumer communication and product positioning.

The identified opportunities indicate where these needs can be addressed through innovation and collaboration, helping companies overcome current barriers and accelerate the successful market uptake of seaweed-based foods in Europe.

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	Cultivation	Processing	Food production	Consumer acceptance
Challenges	• Low production volumes • High initial investment costs • Environmental impact • Complex European regulations regarding cultivation licenses • Competition from Asian market • Chemical, physical and biological contaminants	• Cross-contamination with allergens and biological contaminants • Limited knowledge of preserving seaweed quality • Processing increases operation costs • Fresh products have a short shelf life	• Need for high volume • Need for consistent quality • Lack of knowledge on sensorial, nutritional, and techno-functional properties • Cheaper imported non-European seaweed	• Specific, acquired taste leads to mixed consumer acceptance • Lack of knowledge in preparation of seaweeds • Unique selling points are often missing or unclear • Neophobia • High price • Lack of awareness and accessibility
Opportunities	• Quality control systems (seaweed and growing environment) • Scale-up • Research in genomics, metabolomics, … • Recent advances in sensors and digital twinning of aquaculture systems • Harmonized licensing of seaweed farms	• Wash, boil, dry, ferment or freeze seaweed to prolong shelf life • Post harvest processing can improve food safety	• Clean(er) label • Research can lead to better insights on seaweed properties and their possible uses in product development	• Optimizing sensory, functional and nutritional characteristics through strategic pairing with the right seaweed • Implementation in well-known products • Product differentiation using labels and certifications • Raise awareness of the health benefits

Figure 3: European Supply chain development for seaweed-based food products: challenges and opportunities (WUR, 2018; Valgorize, 2021)

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6.2 B2B Market Survey

As part of their business case within the I3-4-Seaweed project, **Pittman Seafoods** conducted a business-to-business market survey to assess the European food sector's readiness to adopt seaweed as a food ingredient and to identify the key drivers and barriers influencing this transition. Building on the supply chain challenges and industry needs identified in Figure 3 (previous section), this survey provides market validation of the most critical requirements for successful adoption.

The survey targeted potential food industry buyers along the value chain, including a substantial proportion of companies active in the ready-meal segment. In total, **23 respondents** from **five EU** countries participated (response rate: 14%), providing a cross-section of perspectives from industries already engaged in product innovation. While the results should be interpreted as **directional insights rather than being statistically representative**, they nevertheless provide valuable indications of current industry priorities and requirements for successful seaweed adoption.

Overall, the results suggest that while seaweed is perceived as a strategically attractive ingredient category, its successful integration into mainstream product development will depend on achieving a greater level of operational maturity across the supply chain. In other words, **the market is not limited by lack of interest**, but rather by **insufficient confidence in consistent, reliable execution**, particularly regarding supply stability, quality specifications, and functional performance in food applications.

The survey results reveal three levels of market drivers that shape how companies approach the use of seaweed ingredients. **Primary drivers** are the decisive factors for initial adoption and relate to core requirements such as food safety, consistent product quality, cost efficiency, and reliable supply. Only when these essentials are met do **secondary drivers**—including taste and sensory characteristics, regulatory compliance, nutritional benefits, and sustainability contributions—begin to influence how and where seaweed is incorporated. **Tertiary drivers**, such as consumer acceptance and opportunities for innovation and marketing, play a role later in the process by differentiating products but have the least impact on the initial adoption decision. Figure 4 provides an overview of the primary, secondary, and tertiary drivers identified through the B2B market survey.

Market Drivers

Primary Drivers	Secondary Drivers	Tertiary drivers
1. Food safety	1. Taste and sensory characteristics	1. Consumer acceptance
2.Product quality and consistency	2. Regulation/certification	2. Innovation and marketing potential
3. Price level/cost efficiency	3. Nutritional benefits	
4. Availability and supply reliability	4. Sustainbility and CO_2 reduction	

Figure 4: Market drivers for seaweed food ingredient adoption (B2B Market Survey, Pittman Seafoods).

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7. Conclusions

Based on the assessment presented in this report, several key needs emerge that will determine how quickly and effectively seaweed can be integrated into the European food sector.

1

Clarity and alignment in the EU regulatory framework
Although progress has been made, food companies still face uncertainty regarding acceptable levels of heavy metals, iodine, microbiological criteria, and allergens. Clear, harmonised guidance at EU level would significantly reduce this uncertainty and support faster adoption.

2

Reliable and scalable supply chains.
Companies need consistent access to raw materials that meet defined quality specifications, at competitive price levels. This includes improvements in cultivation, post-harvest processing, and standardisation, as well as increased production volumes to achieve economies of scale. Without this level of reliability, seaweed will remain difficult to integrate into mainstream product development.

3

Continued knowledge development and sharing
Knowledge development and sharing, particularly on the functional, nutritional, and sensory behaviour of different seaweed species in food applications, remains important. While significant progress has been made in recent years, and this report contributes to consolidating available insights, further practical, application-oriented knowledge will help companies confidently integrate seaweed into product development and scale up its use.

4

Consumer familiarity
Consumer familiarity remains a key barrier but also one of the most promising opportunities. Increasing awareness, improving accessibility, and integrating seaweed into familiar product formats will be crucial to support wider acceptance.

Taken together, these challenges show that the bottleneck is not a lack of potential, but a need for greater maturity across the value chain. Encouragingly, many of the required developments—ranging from improved processing techniques to better communication and product positioning—are already ongoing. **With the right combination of regulatory clarity, supply chain development, and industry knowledge, seaweed has strong potential to evolve from a niche ingredient into a widely applied, functional and sustainable component of the European food system.**

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Annex

Annex I : Nutritional sheets

The following nutritional information is based on indicative values from CEVA nutritional sheets (available at https://www.ceva-algues.com/en/document/nutritional-data-sheets-on-algae/). These values represent an average derived from multiple publications and research programs. It is important to note, however, that the nutritional content of seaweeds can vary depending on the batch, growing conditions, and seasonality.

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Table 10: Nutritional information of commonly used seaweed species (Ceva, 2019)

	unit	Atlantic wakame / winged kelp	Rock weed/ knotted wrack	Bladder-wrack	Sea spaghetti	Oarweed	Nori	Sugar Kelp, Royal Kombu	Wakame	Dulse	Irish moss	Sea lettuce
Energy	kcal	202	207	197	227	211	257	205	185	221	215	225
g/100 g												
Proteins, total (Nx6.25)	g	**12.2**	7.4	6.4	9.9	8.9	**30.2**	9.9	**14**	**16.9**	**16.7**	**13.6**
Carbohydrates (by difference)	g	13.3	16.3	14.9	26.4	22.9	11.7	23.1	8.7	20.8	15	19.5
Sugars	g	0.04	nd	nd	0.03	nd	0	0.23	0.02	0.02	0.4	1.3
Dietary fibres	g	**42.9**	**43.6**	**46.7**	**30.8**	**37.3**	**36.8**	**30.2**	**36.9**	**29.2**	**35.5**	**35.1**
Lipids	g	1.5	2.7	2.1	2.3	1	1.8	1.4	2.3	1.3	1.9	2.5
Minerals mg / 100g												
Sodium, Na	mg	3 652	2 871	3 477	3 570	3 211	1 900	3 301	5 154	1 873	3 289	4 090
Magnesium, Mg	mg	931	831	872	1 054	770	480	749	1 088	264	1 112	2 257
Phosphorus, P	mg	223	94	100	104	520	491	174	324	250	159	860
Potassium, K	mg	4 310	2 144	3 107	6 773	4 639	1 762	5 912	6 737	7 019	2 304	1 811
Calcium, Ca	mg	771	1 601	1 256	803	918	440	838	963	577	911	1 554
Iron, Fe	mg	44.6	19.3	13.1	2.1	10.5	36.4	24.1	15.5	29.3	18.1	205
Iodine, I	mg	36.2	68.5	40.5	9	458.8	5.6	410	18	22.9	31.3	9.9
Vitamins mg or µg / 100g												
Vitamin D	µg	nd	1	nd	0.3	2.3	0.6	1.3	0	0.9	nd	0
Vitamin E	mg	3.1	14	13	6.6	0.3	3.1	4.3	1.4	4.1	3.5	8.5
Vitamin K	µg	**498.1**	**1 018**	nd	173	nd	225	244	491	467	153	8
Vitamin C	mg	65	89.4	42	**120.5**	11.1	63.9	31.6	36.2	46.9	61.6	48.8
Vitamin B12	µg	2	nd	nd	0.6	nd	**27.2**	2.6	2.4	4.6	1	**31.9**

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Acknowledgements

Vanhegen, K., Coorevits, I., & Van Haecht, A. (2026). Seaweed in food: Insights, opportunities, and industry needs for the European food sector [Project report]. I3-4-Seaweed Project, VIVES University of Applied Sciences.

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