Marine Greens: Exploring the Potential of Edible Seaweeds

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ABSTRACT

Edible seaweeds are increasingly acknowledged at the global level as valuable marine foods, abundant in proteins, dietary fiber, essential vitamins, minerals, and bioactive metabolites. Regular consumption has been associated with multiple health-promoting effects, including antioxidant, anti-inflammatory, and metabolic benefits. In addition to their nutritional significance, seaweed cultivation contributes to environmental sustainability by enhancing carbon sequestration and requiring minimal external inputs. This review underscores the nutritional profile, therapeutic potential, processing methods, diverse applications, and future prospects of edible seaweeds, with particular attention to their role in food security and sustainable development.

INTRODUCTION

Edible seaweeds are rich sources of macronutrients, micronutrients, and bioactive compounds, consumed either directly or as ingredients in various food products. These marine macroalgae, categorized into brown (Phaeophyta), red (Rhodophyta), and green (Chlorophyta) groups, grow along coastlines and rocky shores, playing a vital role in marine ecosystems through photosynthesis. The global production of seaweeds has grown substantially, reaching an estimated 38.5 million metric tonnes (wet weight) in 2023, of which nearly 97% originates from aquaculture. The Asia–Pacific region particularly China, Indonesia, the Philippines, South Korea, and

Japan dominates this sector, contributing about 90% of total cultivation. Valued for their high content of proteins, essential fatty acids, vitamins, and minerals, seaweeds are now widely recognized as sustainable marine crops with the capacity to address future nutritional requirements while strengthening global food security.

Classification of Edible Seaweeds

Edible seaweeds, also known as marine macroalgae, are broadly classified into three groups based on their pigmentation, storage compounds, and cellular characteristics:

1. **Brown algae (Phaeophyta):** These include species such as kelp (*Laminaria*), kombu (*Saccharina*), wakame (*Undaria*), and *Sargassum*. They are rich in alginates, fucoidans, and carotenoids like fucoxanthin with proven health benefits.
2. **Red algae (Rhodophyta):** Important edible species are *Porphyra* (nori/laver), *Gracilaria*, *Gelidium*, and *Kappaphycus*. They are valued for agar and carrageenan production in food and pharmaceutical industries.
3. **Green algae (Chlorophyta):** Examples include *Ulva* (sea lettuce) and *Caulerpa*, which are high in proteins, vitamins, and minerals and consumed fresh or dried in many coastal regions.

Group	Common Species (Examples)	Key Nutrients	Applications
Brown Algae (Phaeophyta)	*Laminaria* (Kelp), *Saccharina* (Kombu), *Undaria* (Wakame), *Sargassum*	Fucoidan, alginates, carotenoids (fucoxanthin), iodine	Soups, salads, functional foods and alginate extraction
Red Algae (Rhodophyta)	*Porphyra* (Nori/Laver), *Gracilaria*, *Gelidium*, *Kappaphycus*	Proteins, vitamins, agar, carrageenan	Sushi wraps, jellies, food stabilizers and pharmaceuticals
Green Algae (Chlorophyta)	*Ulva* (Sea lettuce), *Caulerpa*, *Codium*	Proteins, minerals (Ca, Mg, Fe), vitamins (A, C, B-complex)	Fresh salads, soups and health supplements

Nutritional Profile

Seaweeds are low in calories yet exceptionally nutrient-dense, offering proteins, dietary fiber, and heart-healthy omega-3 fatty acids. They are also abundant in essential vitamins (A, C, B12, K) and minerals such as iodine, calcium, iron, and magnesium, which play key roles in energy metabolism, bone strength, and thyroid function. In addition, seaweeds contain unique bioactive compounds with antioxidant and anti-inflammatory properties, making them a recognized "superfood from the sea." Their cultivation is environmentally friendly, requiring no chemical fertilizers or artificial water treatment (Mahalik and Kim, 2014). Nutritionally, seaweeds are highly efficient: for instance, the red alga *Porphyra* can yield about 84 g of protein per square meter, compared to only 40 g from soybeans and approximately 5 g from meat production. Despite occupying just around 8% of the ocean's surface, seaweeds provide substantial nutritional and ecological benefits.

Health Benefits of Edible Seaweed

The naturally high iodine content of seaweeds plays a vital role in supporting thyroid health, with evidence suggesting that regular intake may even reduce the risk of thyroid cancer (Hoang *et al.*, 2022). Research further indicates that consuming small daily portions can effectively improve iodine status in deficient individuals without altering thyroid hormone balance (Combet *et al.,* 2014). Additionally, seaweed-derived fibers and bioactive compounds contribute to weight regulation and cholesterol management, with clinical studies reporting reductions in body fat and LDL cholesterol following several weeks of supplementation (Rezaei *et al.*, 2023;

Łagowska *et al.*, 2025). Owing to their abundance of antioxidants and anti-inflammatory agents such as polyphenols and fucoxanthin, seaweeds also demonstrate protective effects against chronic health issues, including obesity, diabetes, and cardiovascular diseases (Yadav *et al.*, 2024).

Culinary Uses and Processing

Seaweeds are consumed in soups, salads, broths, and snacks, with nori, wakame, and kombu being most common. Processing methods include drying, blanching, roasting, fermentation, and modern freeze-drying to retain bioactivity. Extracts (alginates, carrageenan, agar) are widely used as gelling and stabilizing agents in food and pharmaceuticals (MacArtain et al., 2007).

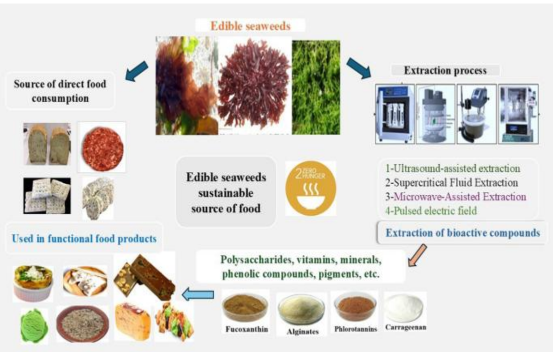

Fig 1 Applications and extraction processes of edible seaweeds.

Cultivation and Sustainability

The expansion of global seaweed cultivation is largely attributed to its low input requirements and significant ecological benefits. Unlike conventional terrestrial crops, seaweeds grow without dependence on freshwater, arable land, or chemical fertilizers, positioning them as a sustainable resource. Cultivation methods such as rope, raft, and net systems are widely practiced, with integrated multi-trophic aquaculture (IMTA) increasingly adopted to enhance nutrient recycling and minimize environmental impacts. Large-scale seaweed cultivation plays an important role in carbon sequestration, nutrient removal, and the reduction of eutrophication, while also enhancing the livelihoods of coastal communities. However, issues such as climate fluctuations, biofouling, and the lack of uniform management frameworks remain significant barriers, highlighting the urgent need for sustainable farming practices that balance ecological advantages with the growing global demand (Chowdhury *et al.*, 2023; Kim *et al.*, 2019; FAO, 2023).

CONCLUSION

Edible seaweeds are nutrient-dense marine resources with the potential to enhance global nutrition and food security. Their abundance of proteins, essential fatty acids, minerals, vitamins, and bioactive compounds supports metabolic health and protection against chronic diseases. Cultivation requires minimal inputs, contributes to carbon sequestration and nutrient recycling, and supports coastal livelihoods. Addressing challenges such as climate variability and farming standardization will be vital to scale production. Overall, seaweeds emerge as sustainable functional foods linking human health with environmental resilience.

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