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# Ocean Superfoods - The Nutraceutical Power of Seaweeds

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**ABSTRACT**

**Mr. Seaweeds are macroscopic marine algae, rich in vitamins, minerals and amino acids. They contain many trace elements and essential nutrients needed to fight against many human diseases, including heart problems, hypertension, sugar problem and cancer. They are characterized by a thallus organization and the absence of true vascular tissues. Taxonomically seaweeds are distributed in major algal groups i.e. in green algae (Chlorophyta), red algae (Rhodophyta) and brown algae (Phaeophta). Red seaweeds are more abundant in subtropical and tropical waters, whereas brown seaweeds predominate in temperate regions. The capability of rapid biomass production and presence of favourable nutritional composition, makes seaweeds a significant contributor of nutritional security, pharmaceutical industry, aquaculture feed, biofertilisers and other agricultural amendments. These attributes are particularly relevant in the context of declining arable soil fertility, stagnating crop yields in many regions, and growing global population pressures that increase the risk of food insecurity. Many coastal states possess extensive bays and lagoons that are suitable for marine farming, yet large-scale cultivation of seaweeds remains underdeveloped. Seaweed culture typically requires relatively low capital and input intensity, can deliver high returns per unit area, and provides opportunities for local employment making it an attractive livelihood option for coastal communities. Strategic investment in cultivation infrastructure, species selection, post-harvest processing, and product development and value-chain integration can**

**increase domestic supply, expand exportable products, and generate socioeconomic benefits for coastal populations. With targeted R&D and investment, countries such as India could become significant producers of seaweed-derived products, enhancing both national food and nutritional security and fisheries export value.**

## INTRODUCTION

Mr. Seaweeds (marine macroalgae) are photosynthetic organisms that have been consumed and used medicinally in coastal communities for the past hundreds of years. In recent decades they have attracted scientific and commercial interest as rich, sustainable sources of nutraceuticals. The nutraceuticals are bioactive compounds which provide health benefits and can be incorporated into functional foods, dietary supplements, cosmetics and pharmaceuticals. Major classes of seaweed-derived nutraceuticals include complex polysaccharides (e.g., Alginates, Carrageenans), polyphenols (phlorotannins), carotenoids (fucoxanthin), bioactive peptides, omega-3 fatty acids, vitamins and a broad mineral profile (Iodine, trace elements) (Plaza et al., 2008). The biochemical diversity of brown, red and green macroalgae underpins a wide range of reported bioactivities. Polysaccharides from brown and red algae have been studied for anticoagulant, antiviral, immunomodulatory and prebiotic effects. The pigment fucoxanthin of brown seaweeds has been investigated for antidiabetic and hepatoprotective effects; and peptides released by enzymatic hydrolysis exhibit ACE-inhibitory and other cardio-protective properties (Wijesinghe & Jeon, 2012; Fleurence, 2016). In addition, the high mineral content and presence of vitamins make some seaweeds useful as micronutrient supplements, though their element concentrations are highly species- and environment-dependent. Despite promising in vitro and animal-model data, translation to human health applications faces several challenges. Natural variability in composition, seasonality, site-specific contamination (heavy metals, excessive iodine), variable bioavailability, and the need for standardized extraction and characterization methods complicate product development and regulatory approval. Sustainable harvesting and aquaculture practices, green extraction technologies and rigorous clinical trials are critical to realize the nutraceutical potential of seaweeds while ensuring safety and environmental stewardship (Holdt & Kraan, 2011; FAO, 2018). Overall, seaweeds represent a compelling and expanding source of nutraceuticals with multifaceted bioactivities and industrial applications. Continued interdisciplinary research integrating phycology, chemistry, food science, toxicology and clinical research is needed to standardize ingredients, clarify mechanisms of action, demonstrate efficacy and safety in humans, and develop scalable, sustainable production systems. Edible seaweeds have long been established in Asian markets and are gaining traction in Europe. Their recent rise in popularity is linked to trends in functional foods and growing consumer interest in diet, health impacts, and food origins. Seaweeds are often regarded as more environmentally friendly and can provide multiple benefits when used as food additives or eaten directly. They can serve as a partial substitute for meat, which the United Nations estimates could increase by about 75% by 2050, making seaweed a potential option to reduce excessive animal-protein consumption and the environmental damage associated with meat production. (Rogel-Castillo 2023).

## INTERNATIONAL SCENARIO OF SEA WEEDS

Seaweed and algal products are a multi-billion-dollar global industry. Modern seaweed aquaculture produces on the order of 30+ million tonnes (wet weight) annually, and the sector's end-market value is commonly cited in the multiple-billion-dollar range worldwide, driven by food, feed, hydrocolloids and industrial uses. Hundreds of algal species are consumed around the world; several dozen species are produced at commercial scale. Both processed and unprocessed algae represent a food industry worth several billion dollars each year. Roughly 500 species are consumed by people, with about 160 having commercial significance. Besides the use of algal extracts in prepared foods, whole algae are eaten across many regions. They are staple foods in East Asian and Pacific Island societies. They are also consumed unprocessed in parts of South America, North America, and northern Europe. The red alga Porphyra is the leading commercial food alga. In Japan about 100,000 hectares of shallow bays and coastal waters are cultivated for it. The microscopic freshwater green alga Chlorella is grown and eaten in Taiwan, Japan, Malaysia, and the Philippines; it is high in protein (53–65%) and has even been considered as a food source for long-duration space missions. Many seaweeds have cell walls rich in phycocolloids such as alginate, carrageenan, and agar which are increasingly used as thickening and gelling agents in various industrial and food applications. While the Far East and Pacific have a long tradition of eating seaweeds as vegetables, Western use has focused mainly on extracting phycocolloids. Seaweeds are also valued as a source of compounds with potential health-protective properties. Historically, seaweed consumption dates back centuries (notably from the 4th century in Japan and the 6th century in China), and today Japan, China, and South Korea are the largest consumers (Kumar et. al., 2025).

## THE INDIAN SCENARIO

Seaweeds are abundant along the coasts of Tamil Nadu and Gujarat and around the Lakshadweep and Andaman and Nicobar Islands. Notable seaweed beds occur near Mumbai, Ratnagiri, Goa, Pulicat (Tamil Nadu) and Chilka (Odisha). Surveys by the Central Salt and Marine Chemical Research Institute, the Central Marine Fisheries Research Institute and other organizations have revealed extensive seaweed resources along South India's coastal belts. On the west coast, particularly in Gujarat, large intertidal and subtidal seaweed stocks are present. India's coastline hosts roughly 844 species of marine algae about 434 red algae, 194 brown algae, and 216 green algae of which some 60 species are commercially important (Kumar et al., 2025). Key commercial species include *Gracilaria edulis*, *Gelidiella acerosa*, *Kappaphycus alvarezii, Sargassum*, and *Turbinaria*, which are used mainly in the food, feed, fertilizer, and pharmaceutical sectors. Seaweed cultivation is attractive for coastal communities because it requires relatively low inputs, offers high returns on investment, and generates considerable employment. Investment in cultivation and downstream product development could help improve India's food and nutritional security and increase the overall value of fisheries exports. Currently, the seaweed industry in India is largely a cottage industry based on natural stocks of agar and algin-yielding species. Production in 2020 was approximately 20,040 tonnes. The sector faces several challenges, including over-exploitation of certain species that leads to raw material shortages, variability in raw material quality, labor shortages during paddy harvesting and transplanting seasons, limited processing technologies to improve product quality, and insufficient information on new or alternative raw material sources. Despite many sheltered bays and lagoons suitable for mariculture, large-scale seaweed farming has not yet been widely implemented. Increasing production will require improved harvesting methods, control of

competing species, creation of artificial habitats, and seeding of cleared areas to expand cultivated stocks.

## VALUE OF SEAWEEDS AS FOOD

While not a mainstream food, seaweed is used as a food in parts of India, particularly along the coasts of Kerala and Tamil Nadu, where it's added to soups or eaten as a leafy vegetable. Recent government initiatives and private sector interest are promoting seaweed cultivation and consumption, recognizing its potential for nutritional security and industrial applications beyond food, though challenges remain in consumer acceptance and regulatory frameworks. As per 2021 data, common edible seaweeds in India are given in (Table 1). In 2021, India produced 34,000 tonnes of seaweed, primarily for use as a food additive rather than for direct culinary consumption.

**Table 1. Common edible sea weeds in India**

| Sea Weed | Scientific name | Group | Uses |
|---|---|---|---|
| **Ogonori** | *Gracilaria sp.* | Red Algae | It is commonly found along the southern coasts of India. It is used to make the gel-like substance agar, which is added to a local summer drink called jigarthanda. In Lakshadweep, it is consumed in porridges, pickled, and fried. |
| **Nori** | *Porphyra spp.* | Red algae | Nori is most famously used to wrap sushi and rice balls, but can also be crumbled as a garnish for salads and fish dishes, or made into snacks and seasonings. |
| **Dulse** | *Palmaria palmata* | Red algae. | It is consumed directly or in vegan "fish" recipes, or added as flakes to dishes for flavor and nutrients. |
| **Irish Moss** | *Chondrus crispus* | Red alga. | It is a as a natural food thickener and stabilizer (carrageenan) in dairy and processed foods. It is also consumed for its nutrient density, supporting immune and digestive health, skin health, and potentially aiding heart health. |
| **Elkhorn sea moss** | *Kappaphycus alvarezii:* | RedAlga | It is commercially cultivated in India to extract carrageenan, a food additive. Despite its common industrial use, some coastal communities consume it directly. |
| **Kombu** | *Laminaria groendlandica* | Brown alga | Kombu is used to make dashi broth (foundational Japanese soup stock), season rice and grains, soften beans during cooking, and flavor various dishes like soups and stews. |
| **Sugar Kelp** | *Laminaria saccharina.* | Brown alga | It has uses in medicine, cosmetics, and industry. It is a good source of iodine for thyroid health. A bundle of dried Laminaria is used as a cervical dilator. |
| **Wakame** | *Undaria sp.* | Brown alga | It is an edible macroalga with an organoleptic profile combining subtle sweetness and a distinct, pronounced flavor, accompanied by a satiny mouth feel. It is primarily used as an ingredient in soups and salads. |

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|---|---|---|---|
| **Bull Kelp** | *Nereocystis luetkeana* | Giant Brown alga | Bull kelp can be eaten raw. However, some harvesters preserve the stipe by slicing it into thin rings for pickling, while the blades may be dried and used as a seasoning. |
| **Hijiki** | *Cystceria geminata* | Brown alga | Hijiki salad is a traditional Japanese Dish. |
| **Sea-palm** | *Sargassum mutica* | Brown alga | It is consumed raw, or is dried and sold in health food stores. Dried sea palm blades are used in soups and salads, |
| **Sarumen (winged Kelp)** | *Alaria spp.* | Brown alga | Alaria seaweed offers various benefits. It is mainly an excellent source of vitamins and minerals. |
| **Peacock's tail** | *Padina pavonica* | Brown alga | Padina can be used as food and fodder, and as a plant growth promoter and biofertilizer. It also exhibits antimicrobial, insecticidal, antioxidant, antibiotic, and anti-inflammatory activities. |
| **Sea Lettuce** | *Ulva lactuca and Monostroma spp* | Green alge | It can be easily eaten in the form of a snack or as salads. They are quite delicate after drying and crumble easily into tiny tender pieces. |
| **Sea Grapes** | *Caulerpa racemosa* | Green Alga | It is used in fresh salads and other dishes. |

## SEA WEEDS AS SOURCE OF VALUABLE NUTRIENTS

Seaweeds are highly nutritious, packed with minerals like iodine, iron, magnesium, and calcium, along with some essential vitamins. They are excellent source of protein and dietary soluble dietary fiber, while being low in fat and calories. Seaweed also contains antioxidants and can be a source of omega-3 fatty acids.

**Table 3. Sea weeds as source of Valuable nutrients**

| Sl. No. | Category of nutrient | Important chemicals and uses |
|---|---|---|
| 1. | **Polysaccharides and dietary fibres** | Seaweeds contain abundance of polysaccharides, which form the majority of their dietary fiber content.. The unique, polysaccharides seaweeds , such as fucoidan, alginate, and carrageenan, provide structural support and have significant prebiotic and health benefits, antiviral, anti-inflammatory, and antioxidant properties. |
| 2. | **Minerals** | The brown seaweeds have been used for treating thyroid goitre since along back. *Fucus vesiculosus* and Laminaria are the main source of calcium. as it contains 1500 to 8000 ppm dry weight. Calcium content |
| 3. | **Proteins** | In India seaweeds are a good source of protein and amino acids. They contain all essential amino acids and various fatty acids like omega-3s , required for human nutrition. |
| 4. | **Lipids** | Seaweeds are source of lipids and fatty acids. While seaweeds are relatively low in total fat, the lipids they contain are rich in polyunsaturated fatty acids, which are vital for human metabolism and can help mitigate chronic diseases. |

| | | |
|---|---|---|
| 5. | **Vitamins** | Seaweeds are good source of vitamins. They are particularly valuable for providing vitamin B12 and D, which are often scarce in plant-based diets. |
| 6. | **Polyphenols** | Seaweeds are an excellent natural source of polyphenols, which are beneficial bioactive compounds with antioxidant, anti-inflammatory, antiviral, and antibacterial properties. Brown seaweeds, in particular, are known to be rich in a unique class of polyphenols called phlorotannins. |
| 7. | **Carotenoids** | Seaweeds are an abundant and cost-effective source of natural carotenoids, which are pigments that provide antioxidant and anti-inflammatory benefits and are used in food and nutraceuticals. Major seaweed carotenoids include fucoxanthin, found in brown algae, and various xanthophylls like lutein and zeaxanthin. |

## ROLE OF SEA WEEDS IN AGRICULTURE

Seaweeds play many useful roles in agriculture. They are widely used as soil amedmants, bio-stimulants, fertilizers of biological origin and animal feed. They can improve crop yields, quality and resilience when used correctly. Brown sea weeds such as Ascophyllum nodosum, Laminaria spp., and Sargassum are common sources of agricultural products. Red and green algae are also used for specific extracts or local applications. See weeds are used in agriculture as fresh or dried incorporation into soil, liquid extracts and bio-stimulants are applied as foliar sprays, coating of seeds with sea weed dried powder or concentrated extract boost germination and early growth. The benefits associated with use of sea weeds are: improved root development and seedling vigour, increased yield and better fruit/vegetable quality in many crops, better tolerance to drought and salinity stress and enhanced uptake of micronutrients and improved soil biology.

Some key roles are listed below:

Seaweeds contain macro- and micronutrients and trace elements that supplement plant nutrition, especially micronutrients that are often limited in soils.

Seaweed extracts contain plant hormones and signalling molecules (e.g., cytokinins, auxins, betaines, oligosaccharides) that stimulate root growth, seedling vigor, germination and early establishment.

Seaweed extracts when used as foliar spray, supply nutrients and growth-promoting compounds quickly and can improve fruit set, size, color and postharvest quality.

Many seaweed products are allowed in organic farming systems as natural fertilizers and bio-stimulants.

Seaweeds can be used in integrated aquaculture-agriculture systems to capture nutrients and recycle them as fertilizer inputs.

## CONCLUSION

Algae remain indispensable ecologically and economically. Modern seaweed aquaculture is a large and growing sector, and research on algal bioactives, climate mitigation potential, and sustainable production is rapidly expanding. Seaweeds serve as a highly nutritious food source for humans and an organic, sustainable resource for agriculture. They are packed with useful vitamins, minerals, and bioactive compounds that promote health and improve soil fertility. Their cultivation offers a regenerative, low-impact solution for food production that mitigates environmental challenges such as climate change, ocean acidification, and land-use pressure. At

the same time, food safety, traceability and environmental sustainability are central to responsible scaling of algal industry. Recent research has highlighted the economic and nutritional importance of edible seaweeds worldwide. Therefore, consumption of seaweeds and seaweed-based products should be encouraged; however, further investigation is needed especially into methods for extracting bioactive compounds that may benefit human health. A specific challenge for the food industry is developing innovative products that incorporate whole seaweeds or their extracts. Although seaweeds offer many health benefits, they can also contain potentially toxic compounds, so expanded monitoring and research are required to assess and manage these risks.

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