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A review of seaweeds: Diversity, culture and global economic impact

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Abstract
Seaweeds, commonly referred to as marine macroalgae, represent a highly diverse group of photosynthetic organisms that play an essential role in marine ecosystems and global industries. This review aims to provide an overview of seaweed diversity, cultivation practices, and their growing global economic significance. Seaweeds are broadly categorized into three groups—brown (Phaeophyta), red (Rhodophyta), and green (Chlorophyta)—each with unique pigments, ecological niches, and commercial importance. The industry is predominantly sustained through aquaculture, accounting for over 97% of total production, with Asian countries, particularly China, Indonesia, and South Korea, contributing more than 90% of global supply. Cultivation techniques such as long-line and raft methods offer sustainable approaches requiring minimal natural resources, making seaweed farming an environmentally friendly practice. Results from global industry data highlight the wide-ranging applications of seaweeds across food, agriculture, industrial, and pharmaceutical sectors. In food and nutrition, seaweeds are valued for their high protein, fiber, vitamins, and minerals, especially iodine. Industrially, hydrocolloids such as agar, carrageenan, and alginates derived from seaweeds are essential as gelling, thickening, and stabilizing agents. In agriculture, seaweed extracts serve as natural biostimulants and fertilizers, while in pharmaceuticals, bioactive compounds are being studied for therapeutic and cosmetic applications. Economically, the seaweed industry is estimated at USD 25.38 billion in 2025, with a projected CAGR exceeding 12% through 2029, reflecting rising global demand for sustainable products. Beyond economic growth, seaweed farming also contributes to climate change mitigation through carbon sequestration and provides vital livelihood opportunities for coastal communities. In conclusion, seaweeds stand as a versatile, sustainable resource with immense potential to support global food security, economic development, and environmental conservation, reinforcing their role in the sustainable blue economy.

Keywords: Seaweeds, macroalgae, aquaculture, hydrocolloids, blue economy, food security,

1. Introduction
Seaweeds, or marine macroalgae, are a diverse group of photosynthetic, non-flowering organisms that form a vital part of marine ecosystems. They are broadly classified into three major groups based on their dominant pigmentation: red (Rhodophyta), brown (Phaeophyta), and green (Chlorophyta). Traditionally, seaweeds have been a staple food in East Asian countries, with their use as a food source in Japan and China dating back to the fourth and sixth centuries, respectively (FAO, 2024) [3].

The seaweed industry has expanded dramatically beyond its traditional culinary applications. Today, approximately 85% of global seaweed production is for direct human consumption, with the remainder processed for the extraction of valuable compounds known as hydrocolloids (FAO, 2014) [2]. These extracts, along with the whole biomass, serve a wide range of uses in the food, industrial, agricultural, and pharmaceutical sectors, making seaweeds a cornerstone of the modern blue economy (MDPI, 2022) [5].

2. Types of Seaweeds
The three main types of seaweeds are distinguished by their pigments and the environments in which they thrive.

2.1. Brown Algae (Phaeophyta): This is the most common and largest group of seaweeds, ranging from small species to giant kelp that can grow over 20 meters long. Their brown or olive-green color is due to the pigment fucoxanthin. Brown algae are typically found in cooler, temperate waters. Key commercial species include Kelp (*Laminaria*), *Sargassum*, and *Fucus* (Bladderwrack). They are a primary source of alginates, a key gelling and thickening agent used in various industries (ThoughtCo, 2025) [9].

2.2. Red Algae (Rhodophyta): Red algae are a highly diverse group, with over 7,000 known species. Their distinctive red color is due to the pigment phycoerythrin, which allows them to absorb blue light, enabling them to live in deeper waters where other light wavelengths are filtered out. Important commercial species include Nori (*Porphyra*), Irish Moss (*Chondrus crispus*), and *Gracilaria*. These species are the main sources of carrageenan and agar, two of the most important hydrocolloids used in food production and microbiology (Humic Factory, 2025) [4].

2.3. Green Algae (Chlorophyta): Resembling land plants, green algae contain chlorophylls a and b and are found primarily in shallow, sunlit coastal waters. They are often smaller than red and brown seaweeds. Common examples include *Ulva* (Sea Lettuce) and *Codium* (Dead Mans Fingers). Green seaweeds are valued for their high protein and vitamin content and are used in salads, biofuel research, and pharmaceuticals (Agriculture Institute, 2023).

3. Seaweed Culture and Production

The global seaweed industry is dominated by aquaculture, with over 97% of production coming from farming rather than wild harvesting (MDPI, 2022) [5]. This cultivation is highly concentrated in Asia, with China, Indonesia, and South Korea leading the world in production volume, accounting for over 90% of the total farmed seaweed (WWF, 2024) [10].

Seaweed farming is an eco-friendly and sustainable practice that requires no land, fresh water, or fertilizers. Common cultivation methods include the single-rope floating raft method, the long-line method, and the bamboo raft method, which are adapted to different marine environments (FAO, 2024) [3]. These techniques involve attaching seaweed spores or seedlings to ropes or nets suspended in the water, allowing them to grow with minimal intervention until harvest.

4. Uses in Various Areas

Seaweeds and their derivatives are used across a multitude of sectors:

4.1. Food and Nutrition: Seaweeds are highly nutritious, rich in vitamins, minerals (particularly iodine), dietary fiber, and protein. Species like Nori are widely consumed as sushi wraps, while others like Wakame and Kombu are used in soups and broths (Humic Factory, 2025) [4].

4.2. Industrial and Chemical: The extraction of hydrocolloids agar, carrageenan, and alginates is a major part of the industry. Agar is used as a gelling agent in desserts and a culture medium for laboratories. Carrageenan acts as a stabilizer and thickening agent in dairy products, while alginates are used in everything from wound dressings and cosmetics to food thickeners (FAO, 2024) [3].

4.3. Agriculture: Seaweed extracts are increasingly used as biostimulants and biofertilizers, helping to improve crop yields and soil health. The rich mineral content of brown seaweeds makes them a natural and effective alternative to synthetic fertilizers (PIB, 2025) [6].

4.4. Pharmaceutical and Medical: Seaweeds are a source of numerous bioactive compounds with potential health benefits. Research is exploring their use in treating various conditions and as ingredients in cosmetics and drug delivery systems (ResearchGate, 2023) [7].

5. Economic Outlook

The global seaweed industry is a multi-billion dollar market, valued at approximately USD 25.38 billion in 2025, with a strong projected compound annual growth rate (CAGR) of over 12% through 2029 (The Business Research Company, 2025). This growth is driven by increasing demand for healthy food, sustainable products, and the expanding applications of seaweed in various industries.

The industry provides a crucial source of income for coastal communities worldwide and offers a sustainable alternative to traditional fishing livelihoods. As the global push towards a "blue economy" and climate change mitigation continues, the role of seaweed farming in carbon sequestration and environmental remediation is expected to further increase its economic and ecological value.

6. Conclusion

Seaweeds are a remarkable and versatile resource with a long history of use and a bright future. As a sustainable and environmentally friendly crop, seaweed farming offers a promising solution for food security, economic development, and climate change mitigation. The diversity of seaweed species and their valuable compounds ensures their continued importance in a wide array of industries, from providing nutritious food to enabling cutting-edge medical applications. As global markets and consumer awareness of their benefits expand, the seaweed industry is poised for continued growth and innovation, cementing its role as a key component of the sustainable blue economy.

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