EDIBLE SEAWEEDS IN CHINA SUPPORT DIETARY DIVERSIFICATION

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This article puts together selected excerpts from the FAO manual "Edible Seaweed Food Guide" which was compiled and published to promote the expanded use of seaweed-based foods, support dietary diversification and contribute to food security and nutrition. While it focuses primarily on the consumption and utilization of each commercially important species relevant to China, other details such as the nutrient content of selected seaweed species and the key processing techniques involved in manufacturing these products as well as the preparation methods for popular dishes are outlined in the publication[1].

Seaweeds, taxonomically classified as algae, play a vital role in marine ecosystems and have long been utilized as a food source in many coastal cultures. Rich in carbohydrates, vitamins, minerals and trace elements such as iodine (Paul et al., 2007), seaweeds typically grow in shallow coastal waters below the low tide line, where wave action is moderate. Their distribution is influenced by environmental factors such as light quality, mineral content and tidal zone.

Globally, over 30 000 species of seaweed have been identified, with more than 70 species considered commercially valuable. These are broadly categorized into four groups: red algae (including *Porphyra, Gelidium amansii, Gracilaria, Chondrus ocellatus, Eucheuma* and *Bangia atropurpurea),* brown algae (including *Laminaria japonica, Undaria pinnatifida, Sargassum fusiforme* and *Durvillaea antarctica),* green algae (including *Ulva prolifera, Caulerpa lentillifera, Monostroma nitidum, Enteromorpha Prolifera* and *Chlorella Vulgaris)* and other algae (including *Spirulina).* Each group tends to inhabit distinct tidal zones, with green algae typically found in upper intertidal areas, brown algae in the mid-intertidal zone, and red algae near the low tide line.

China is the world's largest producer of cultivated seaweed, mainly producing large quantities of *Laminaria japonica, Pyropia* and *Undaria pinnatifida,* with small-scale production of *Sargassum fusiforme, Eucheuma, Ulva lactuca, Monostroma nitidum* and *Enteromorpha prolifera* (Liu, Niu and Sui, 2020). The seaweeds produced in China are widely distributed in domestic and international markets.

China's abundant seaweed resources present significant opportunities for further utilization in the food, pharmaceutical, industrial and agricultural sectors (Li and Fu, 2015). Currently, the food industry represents the largest market for seaweed, particularly in the production of processed products from *Laminaria japonica, Pyropia* and *Undaria pinnatifida.* Seaweed offers an efficient source of nutrition, especially in areas facing resource constraints. However, public awareness of seaweed's dietary benefits remains limited, and its unique taste and nutritional advantages are often underappreciated.

Brown algae *Durvillaea antarctica* (cochayuyo)

Durvillaea antarctica is a genus of brown algae regarded as a rare and premium marine resource, often referred to as a "blue noble food". It is globally classified as a resource under restricted exploitation due to its limited natural availability (Zhang *et al.,* 2024). *Durvillaea antarctica* is primarily distributed in the cold waters of the Southern Hemisphere, particularly around the Antarctic region. It thrives in deep-sea

[1] *Shi, W., Li, K., Wang, X., Jiang, X., He, Y., Yuan, Y., Lovatelli, A. & Yuan, X., eds. 2025. Edible seaweed food guide. FAO Fisheries and Aquaculture Circular, No. 1298. Rome, FAO.* https://doi.org/10.4060/cd7461en

environments and requires precise conditions of light, temperature and salinity.

The nutritional and functional properties of *Durvillaea antarctica* can be significantly influenced by processing conditions. High-temperature treatments, for instance, may alter its physical characteristics, such as swelling capacity, water-holding capacity and oil retention (Guerrero-Wyss *et al.,* 2023). Therefore, in practical applications, it is crucial to optimize both the incorporation rate and the processing method of *Durvillaea antarctica,* depending on the specific requirements of food processing conditions and the intended product attributes.

Credit: Shanghai Ocean University

Cochayuyo can be made into a salad that is spicy and appetizing, with a crispy texture.

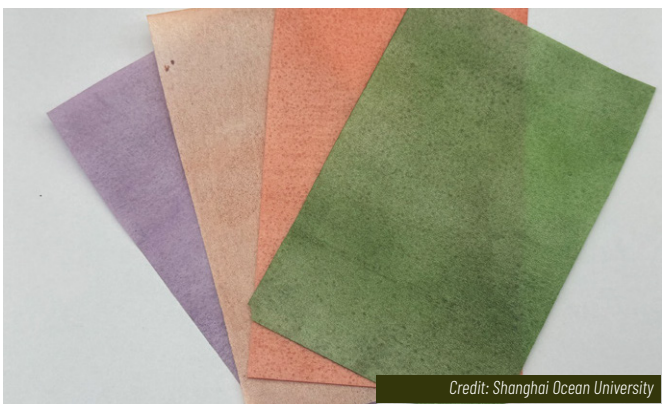
Sargassum fusiforme (hijiki)

Sargassum fusiforme belongs to the Phaeophyceae class, Fucales order and Sargassaceae family and is considered an economically important seaweed (Zou *et al.,* 2012). In China, *Sargassum fusiforme* is primarily distributed along the coast, from the northern provinces of Liaoning and Shandong to the southern provinces of Fujian, Guangdong and Zhejiang. Large-scale farming of *Sargassum fusiforme* is concentrated in the east and south China Sea regions, particularly in the Zhejiang Province.

Sargassum fusiforme has diverse industrial applications, serving as a raw material in the textile, dyeing, food and pharmaceutical industries. Its high fucoidan content makes it especially valuable in the production of colloids and various chemical products. For processing *Sargassum fusiforme,* drying is an essential pretreatment that ensures long-term storage and facilitates transportation. Once dried, this seaweed can be soaked, washed and further processed into ready-to-eat food items or used in the development of innovative products such as health jellies and composite vegetable papers.

Credit: Dalian Ocean University

Credit: Shanghai Ocean University



Credit: Shanghai Ocean University

Credit: Shanghai Ocean University

Top to bottom: Hijiki can be prepared as a salad, jelly, composite vegetable paper and yoghurt

Laminaria japonica (kelp, sea tangle)

Laminaria japonica belongs to the Phaeophyceae class, Laminariales order and Laminariaceae family (Hu *et al.,* 2021). *Laminaria japonica* are primarily found along the Pacific coast of the Americas, from Alaska through the coasts of Canada and California to Mexico, as well as in Australia, Chile, New Zealand and Peru (Matsson, Christie and Fieler, 2019). In China, *Laminaria japonica* was introduced from Mexico in 1978 and has become established in Changdao County, Shandong Province.

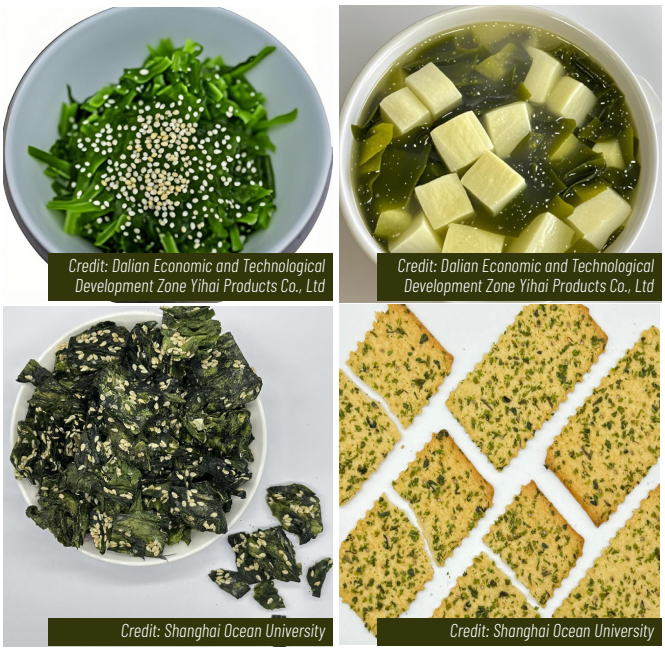
Currently, *Laminaria japonica* foods include dried slices, shredded strips and knots. These dried forms are typically soaked and washed before being used in further food preparations.

Laminaria japonica holds considerable market value for industrial applications, particularly in the extraction of fucoidan. Fucoidan is a hydrophilic macromolecule with excellent adhesion, gelation and film-forming properties (Zhang *et al.,* 2014). Fucoidan has antimicrobial activity and can be used as a preservative in food products (Poveda-Castillo *et al.,* 2018).

There are many ways of incorporating kelp into nutritious dishes for human consumption such as in salads, floss, sauces, soups, sausages, meat rolls, bread, noodles, ice cream, tofu, tea, candy, snacks and others.

Undaria pinnatifida (wakame)

Undaria pinnatifida belongs to the Phaeophyceae class, Laminariales order and Alariaceae family and is an economically important seaweed species. It is distributed in temperate waters around the world, especially in the coastal waters of East Asia, including China, Japan and the surrounding waters of the Republic of Korea (Lee *et al.,* 2004). In China, the Liaodong and Shandong Peninsulas are the primary production areas. Large-scale cultivation is typically carried out using methods such as rope culture and net box culture.

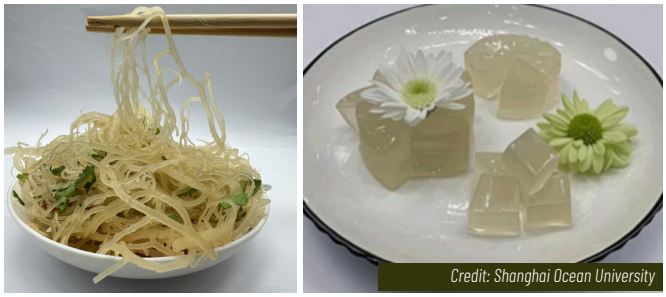


Like most seaweeds, wakame can be used in salads and soups, bread, snacks, sauces, drinks (wine) and others.

Gelidium amansii (Agar weed)

Gelidium amansii is a species of red algae that belongs to the Florideophyceae class, Gelidiales order, and Gelidiaceae family (Pei *et al.,* 2022). It is primarily distributed along the coastal areas of China, particularly in the Shandong Peninsula and in Fujian and Zhejiang provinces. This warm-temperate, perennial seaweed typically grows on rocky seabeds at depths of 6–10 m.

Agar derived from this species is widely used in food processing, pharmaceuticals, textiles and the paper industry. Furthermore, the polysaccharides extracted from *Gelidium amansii* have demonstrated multiple biological activities, including anti-inflammatory, anticoagulant, antitumor and antiviral effects, which underscore its high research and application potential (Lee *et al.,* 2011). Its alcoholic extract is particularly rich in secondary metabolites, especially sterols. These sterols may neutralize free radicals through direct interaction, thereby reducing cellular damage caused by oxidative stress (Li *et al.,* 2014).



Agar weed is consumed in the form of salads and jellies, among other uses.

Bangia atropurpurea

Bangia atropurpurea is a species of red algae that belongs to the Bangiophyceae class, Bangiales order, and Bangiaceae family. It has a broad geographic distribution, occurring across subfrigid to subtropical regions, including coastal areas of Asia, the east coast of Africa, both coasts of the Americas and parts of Oceania. In terms of pigment content, this red alga is especially notable for its high levels of carotenoids and phycobiliproteins (including phycocyanin), which are 4–5 times higher than those in *Porphyra*.

Once dried, this species can be easily rehydrated to regain its original elasticity and fresh taste. Its soft, slightly sweet texture and oceanic flavour make it suitable for cold dishes like gazpacho, as well as soups and seafood-based recipes, where it enhances the depth of flavour. In industrial applications, *Bangia atropurpurea* serves as a valuable raw material for extracting carrageenan and agarose. These compounds are widely used in the food, cosmetics and biotechnology sectors as thickeners, stabilizers and culture media.

Eucheuma

Eucheuma is a genus of red algae that belongs to the Florideophyceae class, Gigartinales order, and Solieriaceae family. It is a type of tropical seaweed commonly found growing on coral reefs. It is widely distributed in warm-temperate and tropical waters, typically from the low-tide line to coastal zones at depths of 1–2 m. In China, *Eucheuma* is primarily found in southern regions such as Hainan Island and the Xisha Islands.

It is well-suited for use in cold dishes, soups and stews, and it is also used in innovative food products such as seaweed noodles. Industrially, *Eucheuma* is a raw material for the extraction of carrageenan (Porse and Rudolph, 2017), a natural hydrophilic colloid widely used in the food, cosmetic and pharmaceutical industries for its gelling, thickening and stabilizing properties.

Gracilaria

Gracilaria is a genus of red algae that belongs to the Florideophyceae class, Gracilariales order, and Gracilariaceae family. It is considered one of the most economically important large seaweeds (Craigie and Wen, 1984). It is widely distributed across the world's coastal regions, particularly along the southeastern coast of China, including the Fujian and Guangdong provinces. Multiple species of *Gracilaria* are cultivated and utilized, such as *Gracilaria blodgettii, Gracilaria bailinae* and *Gracilaria tenuistipitata.* This seaweed typically grows in intertidal zones or near the low-tide line, preferring sunny environments and demonstrating strong adaptability to variations in seawater salinity. It is a fast-growing species and can be cultivated year-round, particularly in the coastal regions of southern China.

In terms of nutritional value, *Gracilaria* is a desirable ingredient for health foods and has been shown to offer several health-promoting functions, including immunomodulatory, antioxidant, hypoglycemic and antiviral effects, as well as benefits for environmental purification. Its high dietary fibre content supports digestive health, helps lower cholesterol levels and assists in blood sugar regulation. In addition to its role in the food industry, *Gracilaria* has significant applications in cosmetics and pharmaceuticals. Its extracts are valued for their bioactive properties and are used to develop products with specific functionalities such as moisturizing, anti-inflammatory and antibacterial effects (Thomas and Kim, 2013).

Chondrus ocellatus (Irish moss)

Chondrus ocellatus, commonly known as Irish moss, belongs to the Florideophyceae class, Gigartinales order, and Gigartinaceae family. It is distinguished by its elongated, flexible branches and is mainly distributed along both sides of the North Atlantic – from Norway to Maine in the United States of America, including Newfoundland in Canada, and as far south as Brittany in France and northwestern Spain.

Porphyra (laver)

Porphyra is a genus of red algae that belongs to the Bangiophyceae class, Bangiales order, and Bangiaceae family. It is naturally distributed along temperate coastal areas in the Northern Hemisphere, particularly in East Asia, including the coastal waters of China, Japan and the Republic of Korea. In China, the southeastern coastal provinces such as Fujian, Guangdong, Jiangsu and Zhejiang serve as the main cultivation bases.

Clockwise: Laver meat floss, laver biscuits, meat/fish balls and fish cakes

Chlorella vulgaris

Chlorella vulgaris is a unicellular, spherical green microalga that belongs to the Trebouxiophyceae class, Chlorellales order, and Chlorellaceae family. It is considered one of the earliest life forms on Earth and was the first microalga to be artificially cultured.

Chlorella vulgaris is a common raw material in animal feed production; it also serves as a natural food source for zooplankton such as rotifers, branchiopods and copepods (which makes it useful in aquaculture). In addition to its high nutritional value, it produces various bioactive compounds, including polysaccharides, flavonoids and polyphenols. These substances exhibit anti-inflammatory, antimicrobial and antioxidant properties and are used in the development of functional foods and nutraceutical products (Lauritano *et al.,* 2016). From an environmental perspective, *Chlorella vulgaris* is highly adaptable and tolerant to pollution. Its ability to absorb and sequester heavy metals makes it an effective agent for environmental remediation and water quality improvement.

Ulva prolifera (green laver)

Ulva prolifera is widely distributed in shallow coastal waters, especially in the intertidal and subtidal zones, where it grows on rocks, sandy beaches and other hard substrates. Due to its strong adaptability and rapid growth rate, it is cultivated in several countries, including China (notably in Fujian, Liaoning, Shandong and Zhejiang provinces), Japan, the Republic of Korea and other coastal nations. Common cultivation methods include raft culture, pond culture and shallow-sea farming.

Green laver soup

Monostroma nitidum

Monostroma nitidum is a large, economically important green seaweed that belongs to the Ulvophyceae class, Ulvales order, and Monostromataceae family. *Monostroma nitidum* typically grows attached to rocks in the mid- and high-tide zones of calm inner bays or on rocky reefs partially covered by mud or sand. Globally, there are 55 known species in the *Monostroma* genus, five of which are found in China. These are distributed along the coasts of provinces such as Fujian, Liaoning (Dalian), Taiwan and Zhejiang. Alongside *Enteromorpha prolifera* and *Ulva prolifera, Monostroma nitidum* is regarded as one of the world's three major economic green algae, accounting for over 90 percent of total green algae aquaculture production (Kaur *et al.,* 2023).

Monostroma nitidum is rich in dietary requirements and is also known for its bioactive compounds, possessing biological functions such as anticoagulant and antiviral activities. In food processing, *Monostroma nitidum* flour is used to enhance the fibre content of noodles; and its polysaccharides can also serve as natural thickeners and stabilizers in food products.

Monostroma nitidum boiled into doughball soup

Caulerpa lentillifera (sea grape)

Caulerpa lentillifera is a large marine algae belonging to the Ulvophyceae class, Bryopsidales order, and Caulerpaceae family. It is primarily distributed in tropical and subtropical coastal zones. *Caulerpa lentillifera* is native to the intertidal regions of the Pacific Ocean and is cultivated in several countries, including China (notably in Fujian, Guangdong and Hainan provinces), Japan, Thailand and Vietnam. It has a long history of artificial cultivation in the Okinawa region of Japan (Chen *et al.,* 2019).

Nutritionally rich, this species offers substantial dietary value; compared to other edible seaweeds, *Caulerpa lentillifera* has relatively higher concentrations of essential trace elements such as iron, zinc, and selenium. It also contains various bioactive compounds such as polysaccharides and polyphenols, which are recognized for their immunomodulatory, antitumor, antioxidant, antidiabetic and antifatigue properties (Da Silva Barbosa *et al.,* 2021; Sommer *et al.,* 2022; Yu *et al.,* 2018). Additionally, it contains unique active compounds like fern sesquiterpenes, which have been explored in pharmaceutical applications for treating skin injuries, gout and diabetes (Yu *et al.,* 2017).

Ecologically, Caulerpa *lentillifera* has demonstrated potential as a biological purifier in wastewater treatment.

Enteromorpha prolifera (sea grass)

Enteromorpha prolifera is a green alga that belongs to the Ulvophyceae class, Ulvales order, and Ulvaceae family. It is typically dark green or bright green in colour, composed of a single layer of cells, and grows in

tubular or band-like forms. The base of *Enteromorpha prolifera* attaches to rocks via a holdfast and commonly grows on mudflats and gravel in mid-tidal zones. It is widely distributed in intertidal areas and occurs along the coastlines of most marine countries worldwide. In China, it is primarily found in the offshore waters of Fujian, Jiangsu, Liaoning and Shandong provinces, with particularly dense natural distributions in Fenghua (Zhejiang Province) and Xiangshan Harbor.

Seagrass can be used in shortbread and biscuit recipes, or fried with fish and shrimp, among other uses.

Spirulina

Spirulina belongs to the Cyanobacteria class, Oscillatoriales order, and Oscillatoriaceae family. Its name derives from its distinctive spiral-shaped structure observed under the microscope.

Spirulina thrives in high-temperature, saline environments and is primarily found in tropical and subtropical freshwater and alkaline lakes. Natural habitats include Chenghai Lake in the Yunnan Province of China, Lake Chad in Central Africa and Lake Texcoco in Mexico. Currently, two main methods are used for commercial *Spirulina* cultivation: open pond systems and closed photobioreactors.

Nutritionally, *Spirulina* is considered a superfood, as its protein content ranges from 50–70 percent by dry weight. One of its key bioactive components is phycocyanin, a pigment-protein complex with strong antioxidant and immune-enhancing properties (Eriksen, 2008). Additionally, *Spirulina* is rich in EAAs such as lysine, methionine, threonine and cystine, nutrients often lacking in cereal-based diets. Beyond proteins, *Spirulina* also contains a broad spectrum of vitamins, minerals (e.g. calcium, iron, zinc, sodium) and other bioactive compounds, earning it the designation as one of the most nutrient-dense foods of the 21st century (Soni, Sudhakar and Rana, 2017).

In food processing, *Spirulina* serves multiple functions: it can enhance colour, flavour and protein content, as well as improve the antioxidant capacity of the final product (Batista *et al.,* 2019). Its addition to dairy products has also been shown to influence microbial activity and the fermentation process (Winarni Agustini *et al.,* 2016). Moreover, *Spirulina* contains bioactive substances such as polysaccharides, polyphenols and phycocyanin, which exhibit antioxidant, anti-aging, anti-diabetic and free radical-scavenging properties (El-Desouki *et al.,* 2015). Owing to these benefits, *Spirulina* is widely used across multiple sectors, including pharmaceuticals, functional foods, dietary supplements and cosmetics.

Spirulina is available in powder, tablet and liquid forms. It is also used in the making of noodles, biscuits and bread.

Summary

Seaweed is abundant across global marine ecosystems and has been consumed by humans for thousands of years. Increasingly recognized as a nutritious and sustainable food source, seaweed is rich in proteins, vitamins, unsaturated fatty acids, polysaccharides, dietary fibre and essential minerals.

In addition to their nutritional benefits, edible seaweeds offer distinctive sensory attributes, such as an umami taste and a pleasant crunchy texture, which have made them integral to culinary traditions in many coastal communities, particularly in China. The growing interest in sustainable, plant-based and health-promoting foods underscores seaweed's potential to contribute to global food and nutrition security.