STM JOURNALS

International Journal of
Sustainability

Volume 2, Issue 1, 2025
January–June
DOI (Journal): 10.37591/IJSU

https://journals.stmjournals.com/ijsu

Review IJSU

Algae as Food: New Prospects in Food Industry

Vaishnavi Joshi*

Abstract

Algae are primary producers in aquatic environments, containing chlorophyll and classified into macroalgae (large forms) and microalgae (microscopic forms). Some algae exhibit mixotrophic (combining autotrophy and heterotrophy) or heterotrophic (feeding on organic carbon) traits. Cyanobacteria (blue-green algae) are a specific type of microalgae, recognized for their prokaryotic cell structure and potential as sources of novel biochemical compounds. Because they provide vital vitamins, minerals, proteins, polyunsaturated fatty acids, and antioxidants, algae are an important part of human nutrition. Microalgae, due to their limited research compared to traditional crops, are considered a promising resource for biomass production, offering high yields in less fertile or non-arable areas. They have an advantage in that they require only simple nutrients (without organic carbon) and can efficiently convert sunlight into biomass and valuable compounds. Microalgae can be cultivated under various conditions, such as nitrogen-limiting environments or mixotrophic cultivation, to increase biomass and metabolite production. With advancements in genetic engineering, microalgae are seen as a promising source for innovative products and applications, making them an important focus for research and commercial exploitation. Another significant kind of algae is seaweed, which is grown all around the world but is specially produced in major producing nations like China, South Korea, and Japan. Based on its pigmentation, seaweed is divided into three primary groups: brown, red, and green. Although seaweed has long been used in Asian cooking, it is also gaining popularity in North America and Europe, particularly France. In areas like California and Hawaii, seaweed's culinary use has been popularized by Japanese communities, helping it gain wider appeal on restaurant menus and supermarket shelves. Overall, algae and seaweed have diverse applications ranging from nutrition to bioengineering and are becoming more prominent in global markets due to their sustainability, efficiency, and nutritional value.

Keywords: chlorophyl, vitamins, minerals, proteins, polyunsaturated fatty acids, antioxidant

INTRODUCTION

Algae are the most prevalent primary producers, although some exhibit mixotrophic or heterotrophic characteristics. In a biological context, "algae" refers to various lower plant groups that contain chlorophyll and are typically found in aquatic environments, though they also thrive in terrestrial habitats. They are classified by size into macroalgae (large, visible forms) and microalgae (tiny, microscopic forms). A specific subset of microalgae, known as blue-green algae or cyanobacteria, are distinguished by their prokaryotic cell structure and are considered a promising source for discovering novel and biochemically active natural compounds. A critical source of vitamins, minerals, proteins, polyunsaturated fatty acids, antioxidants, and other nutrients, algae are grown all over the world for their nutritional value. The significant potential of microalgae is attributed to their relatively limited study compared to traditional crops, their ability to grow in areas not suitable for conventional plants (often with less seasonal dependency), and the fact that some species can produce yields several times

***Author for Correspondence**
Vaishnavi Joshi
E-mail: joshivaishnavi118@gmail.com

[1]Scholar, Department of Botany, School of Basic and Applied Sciences, Shri Guru Ram Rai University, Patelnagar, Dehradun, Uttarakhand, India

Received Date: 03, January.2025
Accepted Date:04, Frbruary,2025
Published Date: 11, February 2025

Citation: Vaishnavi Joshi. Algae as Food: New Prospects in Food Industry. International Journal of Sustainability. 2025; 2(1): 1–6p.

higher than those of terrestrial plants. Microalgae are recognized for their efficient use of sunlight and potential to produce valuable compounds and biomass. They combine traits of higher plants with the rapid reproduction capabilities of microbes, requiring only simple nutrients without organic carbon. By manipulating cultivation conditions, such as limiting nitrogen or utilizing mixotrophic methods, biomass and metabolite production can be significantly increased. With their vast biodiversity and advancements in genetic engineering, microalgae are seen as a promising resource for innovative products and applications. Seaweed can be harvested from natural sources but is increasingly being cultivated. Based on pigmentation, it is divided into three primary groups: green, red, and brown seaweed. Although seaweed has long been used as food in Asian nations like China, Japan, and South Korea, its use has become more and more popular in North America, South America, and Europe. Although seaweed is now grown on every continent, China is the world's largest producer, followed by South Korea and Japan. In France, there has been a notable drive recently to include seaweed in European cooking.

While still viewed as an exotic ingredient in many dishes, seaweed has gained traction in places like California and Hawaii, where significant Japanese communities have popularized it. Its presence on restaurant menus and supermarket shelves has helped broaden its appeal to local consumers.

Protein

Microalgae are rich in proteins, amino acids, and peptides, particularly essential amino acids like lysine, leucine, isoleucine, and valine, which make up 35% of essential amino acids in human muscle. With more than 50% dry weight, chlorella and spirulina have the highest protein concentration. Red and green algae also contain significant protein levels, while brown algae have lower amounts. Notably, Chlorella vulgaris contains 51–58% protein and is widely used in food, animal feed, and medical applications. Ulva species contain all nine essential amino acids necessary for human health, with concentrations that are similar to those found in soybean protein. *Tetraselmis suecica* is a notable source of various vitamins, including thiamine (B1), pyridoxine (B6), niacin (B3), pantothenic acid (B5), and ascorbic acid (C). In contrast, *Dunaliella tertiolecta* is recognized for its substantial amounts of β-carotene (provitamin A), riboflavin (B2), cobalamin (B12), and tocopherol (E). Additionally, Chlorella is rich in biotin (B7). In brown algae, α-tocopherol is the primary form of vitamin E, valued for its stability against heat and acidity but less stable in alkaline conditions, UV light, and oxygen, where it acts as a free radical scavenger due to its phenolic group. Carotenoids, important for their antioxidant effects, are prevalent in many algae, and their antioxidant activity is directly related to carotenoid levels. Studies indicate that xanthophylls from *U. pinnatifida* may be beneficial in treating cerebrovascular conditions. Sea vegetables are excellent sources of vitamins B1, B12, and A, with Nori being especially high in vitamin K, essential for blood coagulation and bone development. Kelp (*Macrocystis pyrifera*) has α-tocopherol concentrations similar to those found in palm, sunflower, and soybean oils. Moreover, Gracilaria chilensis and Codium fragile can have higher β-carotene contents than carrots [1-2].

The vitamin profiles of microalgae vary widely, with *Tetraselmis suecica*, *Isochrysis galbana*, *Dunaliella tertiolecta*, and *Chlorella stigmatophora* being particularly abundant in lipid-soluble vitamins A and E, along with B vitamins such as B1, B2, B6, and B12.

Algae as a Mineral and Vitamin Source

Since algae are a great source of vitamins and minerals, they are especially advantageous as dietary supplements. The vitamin content of some Chlorella species is higher than that of most cultivated crops. For example, the *Spirulina* genus is notable for having more than ten times the amount of β-carotene found in foods like carrots (Mohammed et al., 2011) and more vitamin B12 than any fresh plant or animal source. *Spirulina* is also the highest source of vitamin E, thiamine, cobalamin, biotin, and inositol when compared to green algae, spinach, and liver (Gantar and Svircev, 2008). The most physiologically active form of vitamin E, α-tocopherol, can be produced in large amounts by a number of microalgae. For example, *Euglena gracilis* cultivated in a heterotrophic environment yielded 3.7±0.2

mg/g of α-tocopherol after 120 hours, which is significantly more—up to 95 times higher—than common sources like sunflower, soybean, olive, and corn. If *Tetraselmis suecica* can achieve high biomass yields, it may also compete with *Euglena gracilis* for commercial production of α-tocopherol. Research on six different species of macroscopic marine algae showed folate levels reaching 100 g dry mass = 161.6 µg. Algae may also be used in animal feed as mineral supplements. Filamentous green algae differed greatly in their ash concentration, with *Cladophora* having more than 44%. Numerous edible macroalgae are good food supplements to help meet daily mineral and trace element requirements since they have larger quantities of both macrominerals (8,083–17,875 mg/100 g; Na, K, Ca, Mg) and trace elements (5.1–15.2 mg/100 g; Fe, Zn, Mn, Cu) than edible terrestrial plants.Algal biomass, however, is best regarded as an additional supply rather than a full substitute for artificial minerals or vitamins in animal feeds [3-5].

Algae as a Source of Antioxidants

Algae are recognized for their valuable antioxidant properties._Microalgal biomass serves as a complex antioxidant system, with its efficacy often heightened through interactions among various antioxidant substances. Important water-soluble antioxidants found in algae include polyphenols, phycobiliproteins, and vitamins. As photosynthetic organisms, algae face exposure to intense light and elevated oxygen levels. Oxygen concentrations can increase dramatically in cultures with a high cell density, especially in closed photobioreactors, which promotes the development of strong antioxidant complexes.

For example, the antioxidative capacity of *Spirulina platensis* can increase by 2.3 times when subjected to oxygen stress. The ability of microalgal products to scavenge free radicals is gaining traction in the realm of functional foods and nutraceuticals, especially in the beverage market, where there is a growing consumer demand for health-focused products.

Nori, or Purple laver (*Porphyra* spp.)

The purplish-black seaweed commonly used in sushi is referred to as nori. Its cultivation is predominantly found in Japan, South Korea, and China. In Japan's marine agricultural sector, nori ranks as the highest in production, followed by oysters, yellowtails, and wakame, another edible seaweed. *Porphyra columbina*, a red edible seaweed, is characterized by a significant protein content and a superior nutritional profile compared to many cereals, with protein digestibility akin to that of plant-based foods.[6] It possesses a high mineral content and moderate potential mineral bioavailability (excluding iron), along with low phytic acid levels and an advantageous sodium-to-potassium ratio. Furthermore, *P. columbina* contains bioactive compounds that may exhibit antioxidant properties. Its high dietary fiber content further establishes it as a healthy, low-fat food option. Globally, nori grows into a thin, flat, reddish blade in temperate intertidal zones. Indigenous populations in places including northwest America, Canada, Hawaii, New Zealand, and portions of the British Isles have historically consumed it.

Among the most nutritious seaweeds, nori has a protein content ranging from 30-50%, with approximately 75% of that being digestible. It has a low sugar content (0.1%) and is rich in vitamins, including A, C, niacin, and folic acid, although the stability of vitamin C can diminish in dried forms. During the processing of nori into its characteristic sheets, most salt is removed, resulting in low sodium levels. The high levels of three amino acids—alanine, glutamic acid, and glycine—give nori its unique flavor profile. One of the marine seaweeds that is most often grown is nori. While Porphyra can be harvested from natural habitats, the majority is now derived from cultivation, primarily in Japan, South Korea, and China [7,8].

Chlorella

Chlorella is a green microalga esteemed for its superior nutritional profile relative to Porphyra. Its nutritional makeup is comparable to a combination of spinach and soybeans (Glycine max). Light, carbon dioxide, and vital mineral nutrients are all necessary for the effective cultivation of chlorella, which grows quickly enough to allow for several harvests in a short period of time. Some Chlorella species produce a lot of lipids and proteins; they make up about 30% carbohydrates, 30% proteins, and 15% lipids. This microalga is particularly prevalent in Japan as a dietary supplement, with claims suggesting potential enhancements in metabolic rates and the ability to reduce mercury levels in humans through chelation with its cellular structure [9-10].

Laminaria (Kombu)

Kombu is a type of dried seaweed from various species of Laminaria, primarily harvested in Hokkaido, Japan. The main species include *L. longissima, L. japonica,* and *L. angustata*, which grow on rocks and reefs in shallow waters, typically between 2 and 15 meters deep, in calm conditions and temperatures ranging from 3° to 20°C.In terms of nutrition, kombu consists of about 10% protein and 2% fat, along with various minerals and vitamins, although it has lower vitamin content compared to nori. It includes iodine, a nutrient that nori and many other red seaweeds lack, and is especially high in iron. This makes kombu a key ingredient in traditional Japanese dishes, especially in soups and broths.

Spirulina:

A nutrient-rich algal superfood spirulina is a type of microscopic blue-green algae celebrated as a functional food and dietary supplement. There are numerous health advantages to this all-natural substance. It lives well in warm freshwater environments and is made up of single cells. Since it contains nearly all of the vital elements our bodies require for optimum health and wellbeing, spirulina is regarded as a complete functional food and dietary supplement. It has a long history of use as food in places like Mexico, especially around Lake Texcoco in central Mexico, and East Africa. From its distinctive spiral, filamentous structure observed under a microscope, the term "Spirulina" is derived. With all the essential amino acids present, this algae is one of nature's most concentrated food sources [11-13].

The U.S. FDA has classified Spirulina as "GRAS" (Generally Recognized as Safe), which allows for its widespread use in food. In India, researchers at the Central Tuber Crops Research Institute (CTFRI) in Mysore are studying its application as a dietary supplement. Spirulina is cultivated, dried, and processed into powder form, often sold as tablets. It is composed of approximately 60% protein, along with vital vitamins and unsaturated fatty acids.

Varieties of Seaweed and Their Culinary Applications

Japan leads the world in the production and export of sea vegetables, which is why many varieties are commonly referred to by their Japanese names in the U.S. market. Nori, known for its mild flavor, is best recognized as the dark green wrap for sushi rolls. It contains a lot of omega-3 fatty acids (three sheets contain about 0.01 grams of ALA), which might help keep skin healthy and avoid dryness. Vitamins B12 and C are also abundant in nori [14].

Sushi lovers can take comfort in knowing that nori has lower iodine content than other seaweeds, so consuming a few rolls weekly is generally safe for thyroid function.Kelp is the most commonly consumed type of seaweed and is available in various forms, often sold as dried sheets that can be added directly to meals during cooking or soaked to soften for eating. Kombu, a popular variety of brown kelp, is widely used as a rich source of flavor and minerals in broths and soups. In Japan, kombu is sometimes enjoyed fresh as well. Dark brown seaweed strands have a mildly sweet taste and a firm texture, making them a versatile ingredient in various dishes, from soups and casseroles to baked goods. In Korea and Japan, fresh arame is often prepared by mixing it with sesame oil and serving it on a bed of chopped lettuce. Available in granulated or flake form, kelp can be used as a mineral supplement and as an alternative to salt. Kelp noodles, which do not need cooking, are a low-calorie option (under 10 calories per cup), with no sugar or fat; they are also gluten-free and cholesterol-free, offering 15% of the recommended daily calcium intake. Kelp is extremely high in iodine, with just a quarter teaspoon providing 2,000% of the daily recommended amount. While it can be a beneficial addition for those needing more iodine, it should be avoided by individuals with restrictions on iodine intake. Dulse, a red seaweed found abundantly along the rocky shores of the North Atlantic and Northwest Pacific, has a soft, chewy consistency. You can eat it fresh by sautéing it with garlic and butter. The majority of dulse is usually eaten as dried flake, which improves soup flavor. In addition to being a strong source of calcium and magnesium, dulse has much lower levels of iodine than kombu. Roasted seaweed snacks, for example, provide a salty crunch that is low in fat and calories, making them a healthy substitute for chips [15-17].

CONCLUSION

Microalgae are an underexplored resource that can produce biomass and various compounds, offering several advantages over traditional plants. They can be cultivated with minimal dependence on external environmental factors, efficiently convert sunlight into energy, and do not require fertile land. Additionally, microalgae can synthesize a diverse range of substances, and some species grow rapidly. One of their major advantages is the ability to manipulate growth conditions to control metabolic processes and enhance the yield of specific compounds. By mixing different microalgal species or integrating them with other food sources, there are numerous innovative applications, particularly in animal feed. This not only reduces reliance on conventional crops used for human consumption but can also lower the costs of animal nutrition. As a result, producers worldwide are increasingly targeting the food and feed markets, recognizing the significant potential that microalgae offer. The current oversupply of seaweeds such as nori, kombu, and wakame in China, South Korea, and Japan indicates a saturated market. Japanese nori producers are actively seeking export opportunities, particularly in the United States, to manage surplus production. Given the challenges faced by companies that previously attempted nori cultivation in the U.S., investing in new production facilities may not be a prudent decision at this time. Furthermore, prospective investors in developed countries must first secure rights to the necessary cultivation areas before proceeding.

REFERENCES

1. Blazencic, J. (2007). Sistematika algi. Beograd: NNK International.
2. Carballo-Cardenas, E. C., Tuan, P. M., Janssen, M. H. M., Wijffels, R. H. (2003). Vitamin E (α tocopherol) production by the marine microalgae Dunaliella tertiolecta and Tetraselmis suecica in batch cultivation. Biomolecular Engineering, 20 (4 6),139-147.
3. Christien Enzing, Matthias Ploeg, Maria Barbosa, Lolke Sijtsma. 2014.Microalgae-based products for the food and feed sector: an outlook for Europe. Luxembourgh: publications of the European union. ISBN 973-34037-6.
4. Dennis J. McHugh. 2003. A guide to the seaweed industry, Food and Agriculture organisation of the unite.
5. Gantar, M., Svircev, Z. (2008). Microalgae and cyanobacteria: food for thought. Journal of Phycology, 44 (2), 260–268.
6. Gouveia, L., Batista, A. P., Sousa, I., Raymundo, A., Bandarra, N. M. (2008b). Microalgae in novel food products. In K. Papadoupoulos, Food Chemistry Research Developments (pp. 75-112). New York: Nova Science Publishers.
7. Hasan, M. R., Chakrabarti, R. (2009). Use of algae and aquatic macrophytes as feed insmall scale aquaculture: a review. In Bulletin: FAO Fisheries and Aquaculture Technical Paper, No. 531. Rome: Food and Agriculture Organization of the United Nations (FAO).
8. Manivannan, K., Thirumaran, G., Karthikai, D.G., Anantharaman. P.,Balasubramanian, P. 2009. Proximate Composition of Different Group of Seaweeds from Vedalai Coastal Waters (Gulf of Mannar): Southeast Coast of India. Middle-East J. Scientific Res., 4:72-77.
9. Mohammed, M. K., Mohd, M. K. (2011). Production of carotenoids (antioxidants/colourant) in Spirulina platensis in response to indole acetic acid (IAA). International Journal of Engineering Science and Technology (IJEST), 3 (6), 4973-4979.

10. Plaza, M., Cifuentes, A., Ibanez, E. (2008). In the search of new functional food ingredients from algae. Trends in Food Science & Technology, 19 (1), 31-39.
11. Pulz, O., Gross, W. (2004). Valuable products from biotechnology of microalgae. Applied Microbiology and Biotechnology, 65 (6), 635-648.
12. Rodriguez Bernaldo de Quiros, A., Castro de Ron, C., Lopez-Hernandez, J., Lage Yusty, M.A. (2004). Determination of folates in seaweeds by high performance liquid chromatography.Journal of Chromatography A, 1032 (1 2), 135-139.
13. Rodriguez Zavala, J. S., Ortiz Cruz, M. A.,Mendoza Hernandez, G., Moreno-Sanchez, R.(2010). Increased synthesis of α tocopherol, paramylon and tyrosine by Euglena gracilis under conditions of high biomass production. Journal of Applied Microbiology, 109, 21602172.
14. Ruperez, P. (2002). Mineral content of edible marine seaweeds. Food Chemistry, 79 (1), 23-26.
15. Shields, R. J., Lupatsch, I. (2012). Algae for aquaculture and animal feeds. Technikfolgenabschätzung Theorie und Praxis, 21, 23-37.
16. Singh, S., Kate, B. N., Banerjee, U. C. (2005). Bioactive compounds from cyanobacteria and microalgae: An Owerview. Critical Reviews in Biotechnology, 25 (3), 73-95.
17. Svircev, Z. (2005). Mikroalge i cijanobakterije u biotehnologiji. Novi Sad: Prirodno matematički fakult.

