

Chemical composition of algae and its applications

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Abstract

Algae are photosynthetic organisms that are unicellular or multicellular. They have a lot of nutrients such as carbohydrate, lipid, protein, vitamins, minerals, pigments, and secondary metabolites. Because of that, algae have been used in various industries such as food, medicine, biofuel, and feed for animals. Algae have a lot of bioactive compounds such as alginate, xylan, fucoidan, carrageenan, flavonoids, phenolic compounds, and others. Algae have potential as an antibacterial, antiviral, antifungal, antiaging, antioxidative, anti-inflammatory, and anti-tumor agent. This article aims to give information about the chemical composition of algae and its applications.

Keywords: algae, nutrients, medicine, food, cosmetic

Introduction

The world population which is increasing from year to year has caused an increase in the need for raw materials in the fields of pharmaceuticals, cosmetics, and aquaculture. Algae is one of the organisms that have the potential to be cultivated and developed to meet market needs. Algae are organisms that are quite easy to find in various regions. These organisms are easy to cultivate because they are easy to adapt to extreme environmental changes ^[1].

Algae contain various nutrients such as protein, carbohydrates, lipids, fiber, and others. Bioactive compounds such as alkaloids, phenolics, terpenes are found in algae. The high nutritional content and bioactive compounds cause algae to be widely used in various fields, including in the fields of food, pharmacy, cosmetics ^[2], and also aquaculture ^[3]. In the field of food, macroalgae can be processed into salads, gelatin, noodles, nori, and so forth. Algae have many bioactive compounds that have been shown to have antibacterial, and anticancer, antiviral activity. Algae can be used to treat various skin problems such as anti-wrinkle, whitening, anti-aging, skin moisturizer, thickening agent ^[4]. In aquaculture, various types of algae have also been proven to be used as an ingredient in fish and shrimp feed.

However, This article aims to provide information regarding the nutritional content of several types of algae. Apart from that, this article also explains the bioactive compound content and its benefits. The applications of several types of algae in various fields are also described.

Chemical Composition of Algae Protein

Proteins have important functions for organisms. Protein functions, among others, as bodybuilders, growth (koyande), cell membrane-forming structures ^[5], cell communication, body metabolism, hormone constituents, regulating pH balance ^[6]. For growth, fish need protein around 20-60% and optimum. 30 - 36% ^[7]. The amount of protein that an adult human needs to consume per day is 0.8 g / kg body weight/day ^[8].

Algae is an organism capable of being a source of protein

for human and animal consumption. The protein content in some algae is almost the same as the protein content in animals and plants. Therefore, algae have been widely processed as a food supplement for humans or as a feed ingredient for livestock and fish ^[9]. The protein content in algae varies in various species which are influenced by the type of algae, the environment ^[5] such as light intensity, salinity, temperature, pH, culture age, and nutrient composition ^[10]. The results from the literature listed in Table 1. indicate that the protein content in some algae ranges from 1.86% dw to 51.45% dw.

Lipids

Lipids are also important macronutrients for organisms. Lipids function, among others, as part of the structure of cell membranes, compilers of some hormones, energy sources for various activities of organisms, solvents for vitamins A, D, E, K. Lipids are also a source of essential fatty acids that function for lipid transport, a source of essential steroids that play a role in the formation of steroid hormones (androgens, estrogens, adrenal hormones, and corticosteroids) ^[11]. Lipids are the main macronutrient apart from proteins needed by fish for growth, reproduction, and muscle movement ^[12].

Algae contain phospholipids, glycolipids, and non-polar glycerolipids (neutral lipids). Phospholipids (PL) are located in extra-chloroplast membranes, while Glycolipids are predominantly located in the thylakoid membranes of the chloroplast. Triacylglycerol (TAG) is located and accumulated for storage ^[13]. The lipid content of various types of algae is known to vary from 0.032% to 28.6%

Carbohydrate

Carbohydrates are the main source of energy for organisms. Carbohydrates also play a role as a membrane structure (glycolipids), energy storage as glycogen, a constituent of nucleic acids, spare protein and fat for other uses ^[14], help control blood glucose and insulin metabolism, participate in cholesterol and triglyceride metabolism. Lack of carbohydrates in humans can cause Carbohydrate malabsorption can present with symptoms of constipation,

diarrhea, flatulence, and abdominal pain [15]. In plants, carbohydrates (pectin, cellulose, and hemicellulose) are constituents of cell walls and also play a role in plant immunity [16].

In algae, carbohydrate is a constituent of different cell walls depending on the type of algae. In general, algae cell walls are composed of cellulose, but in red algae, it can be composed of xylan, porphyrin, carrageenan. Green algae can contain mannan, while brown algae can contain alginate or fucoidan. The content of algae in this cell wall is not only influenced by the type of algae but also depends on the stage of development and the environment [17]. Polysaccharides in

the cell wall are also associated with regulating turgor. Carbohydrates in algae are also associated with the process of photosynthesis, energy sources, and carbon storage products [18]. The carbohydrates in algae also play a role in the defense mechanism of the plant body [19].

The carbohydrate content varies depending on various factors, ranging from 7.25% to 86.58% (Table 1). Pasanda and Aziz (2017) [20] reported that the alginate content in *Sargassum* sp is influenced by environmental conditions such as pH and temperature. The accumulation of carbohydrates can also be influenced by the nutritional content found in the media or waters where algae grow [21].

Table 1: Protein, lipid, and carbohydrate content in various types of algae.

Algae	Protein (% dw)	Lipid (% dw)	Carbohydrate (% dw)	Reference
<i>Ulva lactuca</i>	13.6	0.19	58.1	(22)
<i>Ulva fasciata</i>	16.43	2.01	47.32	(23)
<i>Nannochloropsis oculata</i>	30.8	18.5	23.3	(24)
<i>Chlorella vulgaris</i>	51.45	12.18	11.86	(25)
<i>Chlorella pyrenoidosa</i>	45.02	22.89	23.32	(26)
<i>Euचेuma spinosum</i>	7.33	0.032	69.07	(27)
<i>Euचेuma cottonii</i>	5.43	1.47	87.99	(28)
<i>Dunaliella salina</i>	11.3	28.6	38.3	(29)
<i>Hypnea pannosa</i>	16.31	1.56	22.89	(30)
<i>Hypnea musciformis</i>	18.64	1.27	20.60	(30)
<i>Sargassum crassifolium</i>	6.75	0.82	65.01	(31)
<i>Sargassum cristaefolium</i>	8.54	0.25	7.25	(32)
<i>Gracilaria edulis</i>	1.98	0.86	86.58	(33)
<i>Gracilaria salicornia</i>	1.86	0.51	76.18	(33)
<i>Gelidium pusillum</i>	11.31 ± 1.02	2.16 ± 0.61	40.64 ± 2.21	(30)

Vitamins and Minerals

Vitamins and minerals are important micronutrients for organisms. These micronutrients can act as enzyme co-enzymes or cofactors. The regulation of mitochondrial enzymes in metabolic processes also requires the role of B6, B9, and B12 [34]. In algae, micronutrients are also needed for photosynthesis [35].

Micronutrient needs such as the need for vitamin B combinations in various types of algae are different. Lack of these substances can cause interference.

Algae are known to accumulate various micronutrients. The micronutrient content that accumulates in algae varies depending on various factors. These factors are the type of algae, environmental conditions, geographical location, morphological structure, season, cultivation conditions [36].

Many researchers have measured the vitamin and mineral content of various types of algae. *Dunaliella salina* is reported to contain β-carotene (13.14%), tocopherol (1.23%), and ascorbic acid (2.4%) [37]. *Ulva lactuca* contains vitamin B1 (4.87 mg / kg), vitamin B2 (0.86 mg / kg), and vitamin A (<0.5 IU / 100 g) [22]. *Gracilaria corticata* contains vitamin B1 (0.38mg / g), B2 (0.05 mg / g), Vitamin B3 (1.54 mg / g), Vitamin B6 (3.79 mg / g), Vitamin B9 (1.00 mg / g), Vitamin C (14.66 mg / g), vitamin A (2.67 mg / g), and vitamin E (1.40 mg / g). *Gracilaria edulis* contains vitamin B1 (0.36 mg / g), B2 (1.54 mg / g), Vitamin B3 (1.10 mg / g), Vitamin B6 (4.77 mg / g), Vitamin B9 (0.45 mg / g), Vitamin C (13.41 mg / g), vitamin A (2.07 mg / g), vitamin E (1.49 mg / g) [38]. The mineral content of various algae can be seen in Table 2 below:

Table 2: Contents of several minerals in various types of algae

Algae	Sodium (mg / 100 g)	Calcium (mg / 100 g)	Iron (mg / 100 g)	Potassium (mg / 100 g)	Reference
<i>Ulva lactuca</i>	364	1828	14.0	467	(22)
<i>Euचेuma cottonii</i>	1771.84	329.69	2..61	13155.19	(39)
<i>Caulerpa lentillifera</i>	8917.46	1874.74	21.37	1142.68	(39)
<i>Sargassum polycystum</i>	1362.13	3279.06	68.21	8371.23	(39)
<i>Dunaliella salina</i>	35.4	210	4.5	432	(40)
<i>Sargassum naozhouense</i>	3250	66.98	147	4170	(41)

Bioactive compound

Various studies have shown that algae contains various bioactive compounds that have useful antibacterial, antiviral, antifungal, antioxidative, anti-inflammatory, and anti-tumor properties. Green algae contain polysaccharides (amylose, amylopectin, cellulose, inulin, mannan, pectin, xylan). Brown algae contain polysaccharides (alginate, cellulose, fucoidan, laminaran), while red algae contain

polysaccharides (carrageenan, cellulose, furcellaran, mannan, porphyrin, xylan). Algae also contain various pigments that depend on the type of algae such as phycoerythrin, carotene (α carotene, β carotene, lycopene), xanthophyll (astaxanthin, fucoxanthin, zeaxanthin, lutein), chlorophylls (chlorophylls a, chlorophylls b, chlorophylls c). Algae also contain polyphenols, betaines, sterols, terpenoids [42].

The mechanism of the bioactive compound as an antimicrobial is different. Fucoidan can act as an antibacterial by disrupting the bacterial cell wall synthesis process^[43]. Carrageenan can make the virus lose the ability to infect host cells and interfere with the virus adsorption process. Polysaccharides in algae are known to inhibit viral transcription and replication. These polysaccharides interfere with the work of enzymes involved in the process of viral transcription and replication^[44]. Laminaran is known to act as an anticancer by inducing apoptosis of cancer cells^[45].

Applications of Algae

Algae has been widely used for various applications. For aquaculture, algae can be used as an alternative feed for fish and shrimps. Algae also use in the cosmetics industry as thickening agents, water-binding agents, antiaging, and antioxidants. Algae were proved that can inhibit oxidative degeneration of collagen and hyaluronic acid. *Chlorella vulgaris*, *Dunaliella salina*, *Nannochloropsis oculata*, *Porphyra* spp and other are species of algae that can be used for cosmetics^[46]. Algae can be used in biofuel production, human nutrition, food ingredient and nutraceutical, bioremediation^[47], raw materials for making paper, and others^[48]. *Chlorella* is one of the algae that has been produced for human food supplements because of its protein content wordly. Annual production of *Chlorella* reaches 2000-5000 tons^[47]. Alginate from algae has been used to produce drugs for various diseases. Products that use alginate include Natalsid® suppositories (Anti-inflammatory local action), Tromboguard® dressing (Strong haemostatic and antibacterial activity), Progenix putty® (Regeneration, complementation of bone losses), Emdogain® gel (Paradontosis), Purilon Gel® gel (Provides moist environment at wound surface)^[49]. Red algae such as *Gracilaria* sp, and *Gelidium* sp are the raw materials for producing agar. *Ulva lactuca*, *Euचेuma spinosum*, and also *Gracilaria* sp can be processed into human food such as salads. Algae are also widely used in the gelling industry^[50].

Conclusion

Algae which is a sea plant contains various nutrients such as protein, lipids, carbohydrates, vitamins and minerals. Protein content ranging from 1.86% DW to 51.45% dw, lipid ranges 0.032% to 28.6%, and carbohydrate 7.25% to 86.58%. Vitamins contained in algae, namely A, D, E, K, B6, B9, B12 and minerals contained in algae, namely sodium, calcium, iron, and potassium. Algae also has bioactive compounds that are useful as antibacterial, antiviral, antifungal, antioxidant, anti-inflammatory and anti-tumor properties. Utilization Algae applied to industry biofuel production, bioremediation, human nutrition, food ingredient, nutraceutical and farmaceutical.

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