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ALGAE USES FOR ORGANIC LIFE

Ertan Ercan[1], Pınar Yildirim[2], Mustafa Hacisa[1], Cansu Metin[1], Ergi Bahrioğlu[1]
[1]Faculty of Fisheries, Muğla Sıtkı Koçman University, Kötekli, Muğla, Turkey
[2]Çanakkale Onsekiz Mart University, Department of Fisheries Technology, Applied Sciences College, Çanakkale, Turkey

Abstract: The power of the sea has been known since ancient times and marine resources have even benefited mankind when technology was less developed. The use of these resources, both for health and nutritional purposes, is increasingly spreading to other fields today.

Algae produce their own food and have a vital value for life. For this reason, these organic resources have great potential for use in many areas. They are mainly used for medical and food purposes, as fertilizer in agriculture and as a feed source for some animals. Their high levels of protein, vitamins and minerals make these living things valuable as an important source of energy. Containing omega-3 fatty acids, essential for nutrition and development for all living things, provides their usage as food and feed ingredients. In particular, the high amounts of lipid in some microalgae show promise in areas such as biofuels.

This study focuses on the applications of algae based on nutritional and chemical value.

Keywords: biodiesel, cosmetics, feed, fertilizer, food, lipids, microalgae.

INTRODUCTION

Algae which are mostly eukaryotes, live in aquatic environments, and are described as “lower” plants as they do not have true stems, roots and leaves, and they are normally capable of photosynthesis (Hallman, 2007). Algae are plant organisms that carry various pigmentary substances (chlorophyll a, c, d, carotenoid) living in saline and fresh waters. They form the first step of the food chain. They are ecologically one of the most important living group because of providing organic production (Cirik and Cirik, 2004).

It is estimated that the worldwide annual production of algae biomass is about 5 million kg, with a value of 1,650 million US $ (Özçiçek et al., 2017). Approximately 70% of the 253 395 tons of aquaculture in Turkey is produced in Muğla province (BSGM, 2018). Trout, sea bream, sea bass are the main species and micro algae are used in marine species feed regime.

ALGAE CULTURE SYSTEMS

Microalgae are photosynthetic heterotrophic organisms with very high production potentials. Unlike terrestrial plants that require fertile soil and or irrigation, they can grow in a wide variety of the habitats (Özçiçek et al., 2017).

Microalgae production systems can be classified as open or closed. Large pools, circular pools and canal-type pools are examples of open systems. Photobioreactors are commonly used closed systems. Compared to closed photobioreactors, open ponds are a less expensive investment for large-scale production of microalgal biomass. Closed culture systems are often difficult to expand or enlarge. In addition, most closed systems are installed indoors and used artificial light. This results in high energy costs. Open ponds need low energy requirements, have regular maintenance and cleaning is also easier. Open systems are more economical as they use sunlight (Guedes and Malcata, 2012).

Algae, due to their high reproduction characteristics per unit area, have a high productivity potential.

Nutritional composition of algae

Humans are familiar with the use of microalgae as a food source, since ancient times. Algae consumption is promising because of the rapid increase of the world population, and the concern of a possible insufficient protein supply.

Algae contain high amounts of organic substances such as vitamins, proteins, carbohydrates, fatty acids, pigments and because of these features, they have multiple potential uses. Recently, concerns about healthy living has increased especially in the field of nutrition with an increasing consumption of organic food. The addition of microalgae to conventional foods, such as biscuits and bread, enhance their nutritional content and algae have many benefits for human and animal health because of their chemical composition. They can be thought as a novel source of protein and their protein quality is almost better than many high-quality plant proteins.

Microalgae contain mainly lipids (4-55%), carbohydrates (6-57%), proteins (10-63%) (Table 1). Some microalgae strains were also reported to contain more than 70% lipid (based on dry weight) (Elcik and Çakmakçı, 2017). High photosynthetic rates provide carbon retention as well as rapid lipid deposits in biomass (up to 77% of their dry weight). These lipids are composed of glycerol, sugars and saturated or unsaturated fatty acids (12 to 22 carbon atoms). Among all the fatty acids in microalgae, omega-3 (ω-3) and omega-6 (ω-6) families are significantly important. Microalgae also represent a valuable source of nearly all essential vitamins (A, B_1, B_2, B_6, B_{12}, C, E, biotin, folic acid and pantothenic acid) (Spolaore et al., 2006).

According to (Halim et al., 2012) microalgae lipid values range from 5-77% dry weight. The lipid values of microalgae vary according to species, but also vary according to culture conditions such as ambient temperature, intensity of illumination, light/dark cycle and ventilation rate. Algae adapt to challenging conditions such as high-low pressure, temperature, salinity and it was reported that some microalgae can increase their lipid values in the absence of oxygen from 10% to 20% dry weight.

Table 1. General biochemical composition of some algae species (% of dry matter) (Spolaore et al., 2006)

	Protein	Carbohydrate	Lipid
Anabaena cylindrica	43–56	25–30	4–7
Chlamydomonas rheinhardii	48	17	21
Chlorella vulgaris	51–58	12–17	14–22
Dunaliella salina	57	32	6
Porphyridium cruentum	28–39	40–57	9–14
Scenedesmus obliquus	50–56	10–17	12–14
Spirulina maxima	60–71	13–16	6–7

Many marine microalgae contain various fatty acids. *Nannochloropsis, Phaeodactylum, Schizochytrium* and *Thraustochytrium* have been studied due to their high EPA and DHA content. It was reported that total the fatty acids of *Phaeodactylum tricornutum* and *Nannochloropsis sp*. contain up to 39% EPA, *Thraustochytrium* and *Schizochytrium limacinum* contain 30-40% DHA (Adarme-Vega et al., 2014).

Uses

Most simple-sized, single-cell microalgae are mostly used in the food industry. Because of their pigment substances, the antibiotics and vitamins they contain, they are also used in medical and pharmaceutical applications. They also are considered as feed and organic fertilizers in agricultural areas. In addition, recently microalgae, which have begun to be used in biomass production for fuel production. Due to their natural extracts they have become indispensable in the cosmetic industry (Spolaore et al., 2006).

Health

In recent years, algal extracts have proven to have strong antioxidant effects (Yangthong et al., 2009). It has been researched and determined that extracts or pure particles have antioxidant, antimicrobial, anti-tumor, anti-coagulant and antiviral activity (Gupta and Abu-Ghannam, 2011). Most of the health problems encountered today are caused by an insufficient or unbalanced nutrition. For sufficient and balanced nutrition, nutrient components that are essential and balanced are of crucial importance. ω-3 fatty acids and amino acids are also some of the most important components. These important ω-3 fatty acids, EPA and DHA, accumulate in seafood through the food chain. These fatty acids are first synthesized by marine algae and then they are consumed by plankton and other small marine animals in the food chain. Saturated fatty acids can be accumulated in the body, because they are solid at room temperature. Polyunsaturated fatty acids are liquid at room temperature and they are very important, essential and vital for human life.

Insufficient lipids in diets cause skin problems, reproductive dysfunctions; visual problems, and brain development disorders in fetuses. Also, a lack of lipids can cause weakness in memory and mental functions, an increase in coagulation, immune system disorders, growth retardation in infants and children, hair loss, blood circulation disorders, and an increase in blood pressure. A diet deficient in lipids can cause disorders such as kidney dysfunctions, skin problems, and reproductive dysfunctions. It has been shown that a balanced consumption of ω-3 and ω-6 essential fatty acids can bring numerous benefits (Simopoulos, 2002).

Low DHA levels cause brain serotonin levels to drop, which increases suicide, depression, and violence. It has been observed that mental development increases in humans who consumes high-DHA containing seafood (Simopoulos, 2002).

Some proteins, peptides and amino acids of microalgae such as *Arthrospira* and *Chlorella* have health protective effects. Because of the richness of their protein and amino acid profile, they may be used as nutraceuticals or in functional foods as an additive to prevent some diseases and cell/tissue damage (Raposo et al., 2013). *Chlorella* and *Spirulina* also have anti-cancer, immune stimulatory, detoxifying, anti-diabetic, anti-inflammatory, antioxidant, antihypertensive and digestive effects for human health (Kharkwal et al., 2012).

Protein hydrolysates of microalgae can be used for individuals who have digestion problems, cystic fibrosis, and allergies (Gonzalez-Fernandez and Munoz, 2017).

Chlorella improves the immune system, *Spirulina,* the prevention and treatment of heart diseases, *Dunaliella* have a vitamin A precursor feature, *Haematococcus* has an anti-inflammatory effect, *Schizochytrium* ameliorate brain and heart disorders with its healthy lipid content (Kharkwal et al., 2012).

In general, n-3 fatty acids (α-linolenic acid, EPA, DHA) in microalgae are used for the prevention and treatment of many diseases such as cardiovascular diseases, rheumatoid arthritis, cancer, asthma, alzheimer, it also plays an active role in retina and brain development in infants. They prevent heart attacks and lower high blood pressure. Taking EPA and DHA by consuming certain fish and other seafoods, taking linoleic acid (n-3) and α-linolenic acid (n-6) provided by variety of plants and green leafy vegetables in certain ratios is important in the prevention of chronic diseases (Gonzalez-Fernandez and Munoz, 2017).

Food

In recent years, because of rapid increases in the world’s population, inadequate terrestrial nutrients and new nutritional trends, studies about use of algae, which consumed for centuries in some societies, have increased world-wide (Gümüş, 2007). The importance of algae in human nutrition is due to the fact that the necessary ingredients are kept at the desired level in terms of healthy nutrition. The high protein, vitamins, amino acids and minerals in their structure and the low amount of lipids make the consumption of algae, after fish, an attractive food in terms of healthy nutrition (Ova Kaykaç, 2007). They are also marketed as an alternative to fish oil. Their oil can be qualified as better than fish oil because they get their healthy omegas by consuming plankton.

Microalgae for human nutrition are available in different forms such as pills, capsules and liquids in the market. They can also be added to some foods like pastas, cookies, snack foods, candy bars or gums, and beverages (Spolaore et al., 2006). There are many different edible species of microalgae, *Chlorella* and *Spirulina* are two that are used commercially. Both species have a safe use history in the food industry for human consumption. *Spirulina* is sold in tablet and powder form, its consumption has also become widespread in Turkey.

The use of *Chlorella* and *Spirulina*, *Dunaliella, Haematococcus, Schizochytrium, Scenedesmus, Aphanizomenon, Odontella*, and *Porphyridium* is increasing in the food industry and the health-food market. *Spirulina, Chlorella, Dunaliella, Haematococcus*, and *Schizochytrium* are qualified as GRAS by the US Food and Drug Administration *Schizochytrium sp.* is used in breaded milk drinks, breakfast cereals, sauces, baking oil, soft drinks, medical diets, baked goods and sweet biscuits (Gonzalez-Fernandez and Munoz, 2017).

According to Deasang (2015) DHA C22:6n3 (49,1%) and C22:5n6 (21.5%) were found to be the dominant polyunsaturated fatty acids in *Schizochytrium sp., the* EPA C20:5n3 content was determined as 3%, the dominant saturated fatty acid was determined to be palmitic acid C16:0 with 16,4%. Martek Biosciences Corporation (2010) determined that the amount of DHA was at least 22% and the amount of EPA was at least 10% in *Schizochytrium sp*.

Feed

Microalgae are important in the aquaculture of fish and bivalves like oysters, scallops, clams and mussels (Bahrioğlu, 2017). They are an important source of nutrients for the production and development of these bivalves. For this reason, many fish farming facilities also have microalgae production systems. They are used as live feed for zooplankton. Their usage is also common in carp and shrimp aquaculture (Guedes and Malcata, 2012).

Chlorella, Tetraselmis, Isochrysis, Pavlova, Phaeodactylum, Chaetoceros, Nannochloropsis, Spirulina, Skeletonema and *Thalassiosira* are used intensively in fish and poultry feed Due to their high protein content, they are also used as a nutritional supplement. Their consumption results in increased growth rates in animals, egg yolks and even increased wool production in sheep (Hemaiswarya et al., 2011).

In most feed and toxicology studies, microalgae have proven to be an alternative to protein-based feed stuffs such as soybean meal, fish meal, rice bran (Guedes ve Malcata, 2012).

Fertilizer

Algae have a potential for fertilizer and soil improvement purposes (McHugh, 2003; Marinho-Soriano et al., 2006). Because of the macro and micronutrient content; polyamines, natural enzymes, carbohydrates, proteins and vitamins they ensure improved vegetative growth and yield. They contain nitrogen and potassium at suitable rates for use as fertilizer. They a have high water retention capacity due to the high content of insoluble carbohydrates (McHugh, 2003). Algae are utilized either as a liquid extract or directly mixed with the soil in many countries. It is aimed to maintain soil productivity by correcting the structure of the soil when it is mixed directly with the soil. By providing strong root development, they enable plants to absorb more nutrients and water from the soil, to accelerate the formation of chlorophyll, thereby increasing the green leaf areas, and therefore to produce more substances like carbohydrates, proteins etc., and to make the plants more resistant to diseases and pests (Yazıcı and Kaynak, 2001).

Biodiesel

Microalgae have begun to be seen as a possible energy source as a consequence of increasing oil prices in recent years. Their ability to accumulate high levels of oil and their photosynthetic yield, higher than terrestrial plants, makes microalgae attractive for biodiesel production. The production of biodiesel, a renewable energy source, from microalgae has the potential to contribute to the increasing global energy demand and, in part, to contribute to the prevention of global warming by retaining carbon dioxide by photosynthesis (Say et al., 2010). Biodiesel from microalgae is an attractive, feasible, alternative because some microalgae species can significantly increase production of lipids under certain conditions and the cultivation of microalgae is now possible with cheaper heterotrophic cultivation methods(Perez-Garcia et al., 2011). Microalgae are a promising source of biofuel due to their ability to accumulate lipids and their high photosynthetic yields; about 3-8% of solar energy can be converted to biomass compared to terrestrial plants(about 0,5%) (Halim et al., 2012).

Bioplastics

Bioplastics or organic plastics are a form of plastic made from renewable biomass such as vegetable oils and starches unlike fossil-fuel plastics which are derived from non-renewable petroleum sources. Algae act as an excellent source material for bioplastic production having many advantages such as high product yields and the ability to grow in a range of environments (Zeller et al., 2013)

Cosmetics

Among all marine living things microalgae extracts are mainly used in the formulation of cosmetic, skin care and hair care products. There is a growing trend in marine microalgae and they are a great alternative to flower and plant extracts being natural and sustainable. Novel extracts from marine microalgae are a rich source of bioactive proteins (amino acids, peptides, collagen, gelatin), vitamins, minerals, carbohydrates and carotenoid pigments (Wang et al., 2015).

The extracts from *Arthrospira* and *Chlorella*, unicellular green marine microalgal species are used commercially in the cosmetic industry to make skin care products. They have anti-oxidant, anti-wrinkle activity. *Chlorella*, contains various valuable proteins and has great potential to be used in novel cosmeceuticals. *Duniella salina* as a cosmeceutical vehicle to deliver dead sea minerals into the skin. The extracts from *Arthrospira* and *Chlorella*, are used in the cosmeceutical industry to make anti-aging skin care products. (Kim, 2012).

Carotenoids and fatty acids of algae are also promising. Pigments can be used in sunscreen products. Fatty acids help repair tissues. Vitamins A and C have anti-aging activity and the polysaccharides of microalgae are thickening agents and can be used as moisturizers in cosmetic formulations (Kim, 2012).

Pigments

Microalgae are also rich in pigments like chlorophyll, carotenoids, β-carotene, and lutein(Table 2). *Haematococcus pluvialis* is natural source of astaxanthin. These molecules have a wide range of commercial applications (Spolaore et al., 2006). They are used as natural food colorants, as an additive for animal feed (poultry, fish), in cosmetics and have therapeutic properties (act as provitamin A), anti-inflammatory properties. (Kim, 2012).

Table 2. Commercial microalgal culture systems currently in use (Carvalho et al., 2006)

Microalgae	Pigment	Commercial Use	Culturing System
Chlorella spp.	astaxanthin	pigmenting agent	Circular ponds with rotating arm
Dunaliella salina	β-carotene	pigmenting agent	Extensive open ponds
Spirulina platensis	phycocyanin	food coloring	Intensive and extensive ponds
Haematococcus pluvialis	astaxanthin	pigmenting agent	Intensive and extensive ponds

CONCLUSION

As given in here, algae can find many uses in many fields. According to the decreases on fossil energy resources and foods, mankind explore every options that nature gives to us. Renewable energy and food is necessary for environmetal sustainability and economics. Every year earth looses large amounts of soil by the way of erosions. So soil is very important and valuable for agriculture. Algae production is supposed to support the protein, fat, carbohydrate and energy obtained from fossil fuels and agriculture, and may be an alternative at some points. Production potential of the high amount of algae in low surface area available is a testament to being a source of raw materials for many new industries. Organic use and purity of algae is differentiate according to its culturing, harvesting and obtaining methods. The potential use of algal products as organic products are delevoping day by day.

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