ESKİŞEHİR TEKNİK ÜNİVERSİTESİ BİLİM VE TEKNOLOJİ DERGİSİ
C- YAŞAM BİLİMLERİ VE BİYOTEKNOLOJİ

Eskişehir Technical University Journal of Science and Technology C- Life Sciences and Biotechnology

2019, 8(1), pp. 141 - 150, DOI: 10.18036/aubtdc.426379

REVIEW

IMPORTANCE OF ALGAE AND EVALUATION IN INDUSTRY

Fevzi YAŞAR *

Chemistry and Chemical Process Technology Department, Vocational School, Batman University, 72100, Batman, Turkey

ABSTRACT

Algae (unicellular microalgae) are living things that are able to perform microscopic photosynthesis and live on the land and in the sea. They are evaluated to have started life and conveyed it to the land; and they are stated to have existed for 5 billion years by scientists. It is known that about 30,000 types of algae, estimated to exist in a range from 200,000 to 2-3 million types in nature, have been recorded so far; and that merely a few types of them have been able to be commercialized. Algae have highly rich carbohydrate, protein and especially oil acid content. Algae, rich in terms of nutritious value, are the most crucial source of nutrients, vitamins and trace elements for living things in water. They also supply necessary basic pigmentation development for fish and other sea creatures. Algae, one of the most significant food sources of marine life, are used as energy, food, agriculture, cosmetics, medicine and pharmacy, nutrients and mineral source. Also, it is known that they are used in numerous fields of industry such as forage, fertilizer, waste treatment, and dentistry, alcohol, pharmaceutical, paper, paint, rubber, textile, industry, and in their usage of solid and liquid oils and hydrocarbons and aquaculture and waste water treatment. The aim of this study is to emphasize usage of algae, one of the most important sources of marine life, and draw attention to the importance of algae culture and related industry.

Keywords: Algae, Industry, Algae culture, Algae usage fields

1. INTRODUCTION

Algae surviving on earth have quite a wide variety. The reason for this is the cases of their prokaryotic and acratic cell properties, the structure of their cell nucleus and pigment distribution existing in their chromophore structures, the diversification in their reproduction and their flagellate. Algae can survive in quite diversified places in ecosystem. Basically, algae survive in lush areas; besides, they are able to survive snowy and icy areas as well. As a result of investigations, it has been determined that a very significant proportion as 70% of algae on Earth has been flourishing in wetlands. The basic function of algae in wetlands is to produce organic carbon compounds in these areas as major products. The habitats of algae are likely to display diversities even in wetlands. Thus, while some types can live in merely salty waters, other types can survive even in hot spring waters having rather high temperatures. However, lakes and seas are known to be the habitats of algae [1]. Besides supplying the food source of many marine creatures, algae are very important in the respect to produce two third photosynthetic carbon of the world and protect the unification of whole ecosystem [2]. Algae perform significant roles in terms of function and existence of water ecosystem. The carbon dioxide existing in waters is converted into carbohydrate by algae with the help of light. This conversion process is realized via pigments present in the structures of algae. As a result of this conversion process, oxygen solved in water medium and nutritional values exhibit rise. Algae, therefore, are called as premier producers owing to this process. The role played by algae places them in the first ring of food chain.

Algae have extremely rich carbo hydrate, protein and especially oil acid content. Algae, rich in terms of nutritional value, are the most significant food stuff, vitamin and trace elements for living things in water. At the same time, they provide the essential pigments necessary for colourizing of fish and other water beings [3]. In general, though it changes according to genre, algae are likely to contain oil

*Corresponding Author: yasarf75@gmail.com
Received: 23.05.2018 Accepted:05.09.2018

ranging approximately from 15% to 77%. Algae are organisms which make use of sun-light and CO2 more effectively compared to other oil crops while producing oil in their structures; and their split rate and growing speed are considerably high. The biomass doubling period of algae is 3,5 hours during fast growth. For these reasons, it is possible to harvest algae in greater amount in smaller areas with lower costs compared to oil crops the cultivation of which is carried out in large agricultural areas. Algae have significant role in protecting the unification of all ecosystems. Diatoms in the oceans and microscopic algae produce two third of photosynthetic carbon needed by the whole world. In addition to supplying oxygen for living beings in waters by means of photosynthesis realized by them, algae also meet the food and protection needs of living beings in waters. Since the end of 17th century, it has been known that "potash", used in producing soap, glass, soda and fertilizer, has been obtained out of the ashes of burnt brown mosses. Bromine and iodine, taking place among chemical substances, have been isolated from this ash for the first time; and it has been known that iodine is still obtained from sea algae in Japan. Algae, today, are the most effective and economical substances known to treat water and convert solar energy into biyo-mass, which has become branches of industry. On the other hand, they are evaluated in production of energy and some chemical substances (methane gas). Most of the single celled algae are assessed in food sector; and due to the pigments, antibiotics and vitamins they possess, they are used as additives in medicine, pharmacy and cosmetics. Algae are also used as human and animal food. Algae, used as organic fertilizer in agricultural areas, are also a significant food source used in growing phase of fish genera. Therefore, algae are the first and indispensable food stuff of seafood [4]. In addition to all these, algae are important food source in Eastern Asian countries. They are rich in A, A1, B2, B6 and C vitamins and iodine, potassium, iron, magnesium and calcium. In China and Japan about 70 and 20 algae are used in dishes, respectively.

1.1. Algae Production System

Algae can be found everywhere on earth in which they are able to make use of light for photosynthesis since they are organisms containing chlorophyll. Although pool type open systems are used in general, closed photo bio-reactors are also being used to grow algae. The fact that investment and operating costs of the open pools are low has brought it to a position to be preferred in industry. However, the difficulty in controlling production conditions and contamination risk appear to be the disadvantages of system. In large scale culture systems, it is necessary to compare the fundamental issues such as efficient usage of light, heat and providing continuation of culture and hydrodynamic balance in algae culture. The ideal development of each algae genre occurs in the culture mediums where specific conditions are provided. For instance, Spirulina, with high pH and bicarbonate density, Chlorella, in mediums rich in food, Dunaliella salina, in high saltiness, exhibit the best growth. Some production technologies used for algae production are given below.

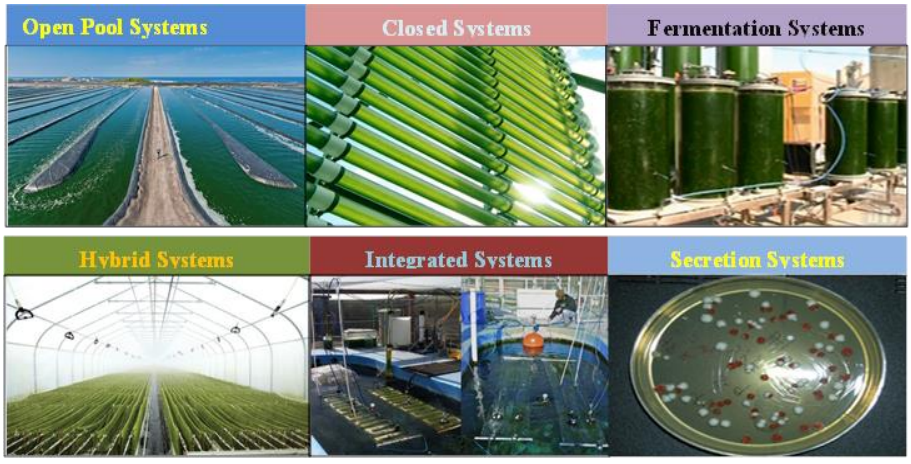

Figure 1. Some production technologies used in algae production

In order to realize the production in most efficient way;

- Effective light usage and surface volume rate to provide this,
- Possibility to operate in cultures with high density,
- High spatial and volumetric production,
- Providing a balanced, quality and constant production,
- Preventing contamination risk led by other genera,
- Permitting the transfer of high amount of CO_2 and low amount of CO_2 loss,
- When set up in outdoor environment, utilization from solar energy at the top level; and accumulated oxygen should be disposed quickly.

1.2. Usage Areas of Algae

Mosses, the most important living sources of seas, are used almost all fields of industry. Especially, algae, which have wide usage field in medicine, pharmacy and cosmetics, and in fertilizer production in the field of agriculture and also which are used as foodstuff in Far East and South Asia countries, are not only collected naturally but also their cultures are produced and cultivated on the land and in the sea. Besides, algae have great significance for other sea beings. In Far East countries, where land is scarce but population is high, it is known that the algae have been an important food source since the 17th century. Until today, algae have not been consumed as foodstuff in European countries and the US; however, they have been used in many fields with the new facilities that biochemical and technological researches have put forward [6-7]. In order that the algae industry will not encounter problems, besides making use of them naturally proliferating in the sea, researchers have followed the way to utilize the cultures of these algae [8]. In addition, since algae have more oil content compared to land plants, they have gained significance as raw materials for energy. The utilization cycle from algae is given in Figure 2.

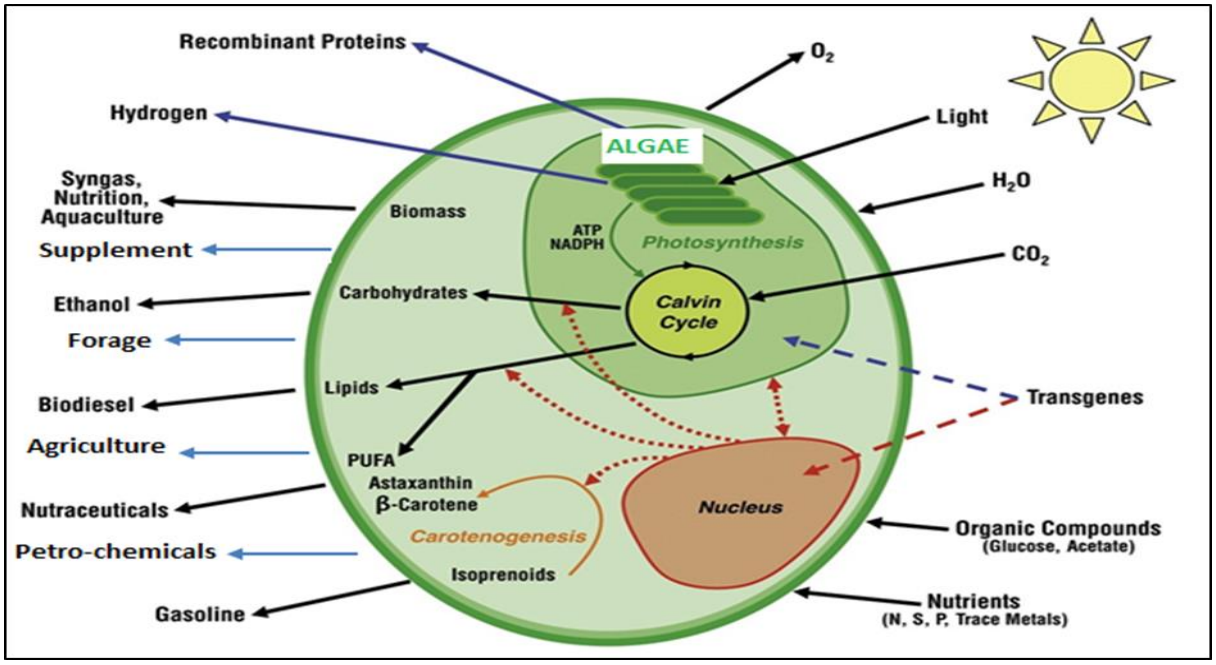

Figure 2. The Application fields of algae

Diatoms, from the single celled water algae, are the most important algae used in industry today. Diatoms, having thrived during geological eras, made thick layers consisting of siliceous shells precipitating at the bottom of the seas. They are encountered near Ankara, Erzurum, Kayseri and Afyon in Turkey. The colour of this soil is either dirty white or white; and it is light; and it contains

60-90% of silica. Since it absorbs 2-4 times more water than its volume, it is used in packaging harmful substances such as acid, and in insulating of furnaces as it does not burn and convey heat, and in cleaning metallic wares as it is hard, and in producing dynamite being mixed with nitro-glycerine and in filtrations. Some of luminaria types of brown water algae are used in obtaining alginic acid and salts. This is used in preparation of tablets and suspensions in pharmacy technique, and in food industry, and in conservation of food, and in cosmetics industry and in textile industry a lot. Of its fucus types, they have been utilized to obtain iodine. And also, of its Gelidium types which are red water algae, they are utilized to obtain Agar. Agar carries poly-saccharides in its structure. It is used in treatment, bacteriology, pharmaceutical industry and food industry. Below, you can find some algae types and their application fields [9].

Algae Type	Product	Application Fields
Chlorella Vulgaris	Biomass	Healthy Food, Food Supplement, Forage, Cosmetics, biofuel,
Spirulina Platensis	Phycocyanin (Algae Pigment), Biomass	Healthy Food, Food Supplement, Forage, Cosmetics, Functional Food, Biofuel
Dunaliella salina	Carotenoids, β -Carotene	Healthy Food, Food Supplement, Forage, Cosmetics
Nostoc fusiforme	Biomass	Healthy Food
Aphanizomenon flos-aquae	Biomass	Healthy Food
Haematococcus pluvialis	Carotenoids Lining	Medicine, Forage Additives, Water Product Cultivation
Crypthecodinium	Docosahexaenoic acid	Baby food
Odontella aurita	Eicosepentenoic acid, Biomass	Cosmetics, Food
Schizochytrium	Docosahexaenoic acid	Baby food
Sceletenoma	Life Biomass	Water Product Cultivation
Nitzschia/ Navicula	Life Biomass	Water Product Cultivation
Isochrysis galbana	Life Biomass Oil Acids	Water Product Cultivation Animal Food
Nannochloropsis	Life Biomass	Water Product Cultivation , Biofuel

Figure 3. Application fields of some of algae types

Today, about 120 species of algae have been found belonging to the classes mentioned above in our country. Yet, Japan, in the world, comes first among the countries making use of algae and producing their cultures. The usage fields of algae are given below.

1.2.1. Usage of algae in the field of food

Great majority of algae is consumed as food. In Far East countries, they are consumed both as salad and their soups, meals; and sauce is also cooked out of them. When nutritional analyses of red algae are made, it is established that their contents are of carbohydrates, proteins and oil acids. The algae, complete source of protein, consist of many amino acids necessary for living things [7]. Algae are sold in Japan as ready foodstuff under the names such as “Asaksanori, Suschi, Amanori, Tjinitiow, Kanten, Kombu”; and also consumed as tea. In the west, although algae constitute limited amount of food, the interest in algae has increased considerably in recent years. The substances such as agar-agar, karragen, aljinat called as “jelatan” mostly obtained from algae in the kitchens of these countries have found a wide range of use. With their jellying, intensifier, suspender, it is used in making cake, jam, marmalade and ice-cream. It is also used in preparing the cover of sausage in industry and in preserving fatty fish like mackerel in European countries [8]. Venezuelan people are fed with 35 gr planktonic soup a day; and it is witnessed that these people are very healthy.

1.2.2. Usage of algae as animal forage

Today, algae, in many countries, are mixed into forage and very good results are obtained. For instance, in the Netherlands, milk production and vitamin A in milk increased after the animals were fed with forage which were mixed with algae flour; and the wool and meat yield of lambs increased by 20% with abovementioned method. In Canada, in addition, the amount of fat in the milk and in Norway, the egg yolk increased considerably with the help of forage containing algae. The reason for this is that the nutritional value of algae is high. The algae used for these purposes generally possess approximately 20% protein of their dry weight. Cystoseria types found in the seas around our country are the algae which can be utilized in forage industry [9-11]. In the investigations carried out on poultry, it was witnessed that the weight of poultry increased more than 25% compared to controls when algae are added to the forages instead of soya protein.

1.2.3. Usage of algae in agriculture

Algae are evaluated as fertilizers in many countries since they have the features to aerate the soil and to keep moisture, and exhibit the abundance in nitrogen as much as fertilizer and harbour trace elements in them. Particularly, algae fertilizer mixed with super phosphate gives good results in soils where potatoes are grown and which are poor in potash. Cystoseira, Enteromopha and Ulva types of them can be used for this purpose. In addition to all these, algae have various functions as bettering the soil in terms of decreasing the erosion, providing aeration, facilitating water flow, bettering root development, facilitating the cultivation of the soil and arranging the growth of the plant [12].

1.2.4. Usage of algae as foodstuff

More than 100 algae types most of which are Phaeophyceae and Rhodophyceae types are used as foodstuff by people in different parts of the world due to the presence of protein, carbohydrate, vitamin and minerals they have. It is known that some algae types eliminate bacteria causing bad smell and support digestion system by strengthening the immune system. Apart from being a good source of protein, vitamin, mineral and chlorophyll, algae have the protective properties against cancer and anti-tumour effect. Besides, algae eliminate the side effects of a diet program such as exhaustion, weakness etc. by increasing energy level; and they help to lose weight healthily preserving energy level. Moreover, algae inhibit the effects of aging by decreasing the influences of harmful substances such as free radicals, air pollution, cigarette, alcohol etc. It is also known that some types of algae help the body to be protected and purified from the toxic effects of metals such as mercury, lead and radiation [13-14].

1.2.5. Usage of algae in waste water treatment

The wastes emerging from domestic and industrial sources contain dissolved or hanging organic and inorganic compounds. The water treatment processes of these wastes occur in oxygenated environment and this oxygenating is provided by some algae. In addition to this, some compounds such as nitrogen and phosphor which are difficult to purify can be disposed from the environment by being taken into algae tanks and these harmful substances are consumed as food by algae [15]. Algae are organisms widely used in water treatment due to their ability to eliminate dissolved phase accumulating the basic pollutants in their cell and cells posing threat to water eco-systems such as nitrogen and phosphor initially and nutrients, heavy metals, pesticides, organic and inorganic toxins and radioactive substances in waste waters. Among the biological treatment methods, the systems in which algae are used have gained speed in the last 50 years. The fact that with this method of treatment waste water, equivalence and more amount of water treatment is obtained compared to traditional methods where complex and expensive chemical processes are used, and that it necessitates less capital and maintenance cost make these algae cultures very profitable. Therefore, this makes algal waste water treatment an important alternative for urban and industrial waste water treatment.

The fact that it is possible to produce energy from methane obtained from the fermentation of algae in waste water pools, and that the purified water can be used as irrigation water, and that it is possible to dispose the toxins, extremely hazardous for aquatic life, such as selenium are all indicators that algal waste water treatment systems will find a wide usage area in the near future [16].

1.2.6. Usage of algae in dentistry

Some algae types are used in producing alma substance for tooth impression which rapidly hardens and do not spoil easily. Among the significant properties of algal extracts are those of antimicrobial properties such as being ant-inflammatory, tooth paste, mouth-washing, functional gum. Hydrocolloids present in algae and their extracts are used as pressure materials in dentistry since they have the features to be gelled and water binding [13, 17].

1.2.7. Usage of algae in alcohol industry

In addition to be used as beer and wine clarifier, they are used as stabilizer to prevent cocktail mixtures from precipitating. They are also used so that foam will occur in beer for beer and wine clarification. Spar colloid, a special purification supplement substance, reproduced from alginic acid present in brown alga, is very effective in establishing the fine hanging particles. And therefore, it is recommended for red wine though it is convenient for white wine. In addition to this, another benefit of spar colloid is that it increases the filter efficiency if wine is filtered due to greatness of sediment density [13, 18].

1.2.8. Usage of algae in medicine and pharmacy

They are used for separating substance and filling matter in tablets to gain fluidity the solutions of fat and paraffin. It is known that they are used in manufacturing low caloric and satiate food by making antibiotic, hormone and vitamin drinkable using them in covering the tablets. It is also known that algae are used in injury treatment, eliminating heavy metal poisoning, in balancing immune system, in reducing high fever, in adjusting blood circulation, in regenerating the skin, eliminating embolism and in reducing cholesterol [19]. As a result of the studies carried out, the regulating effect of 30 algae types on immune system has been established. The most impressive aspect of these investigations is antiviral property of each species against many pathogens. According to the researchers' opinion, these algae provide resistance against bacteria, fungi and viral pathogeny.

In some communities, because of their rich fibre, mineral, protein, low fat and digestible carbohydrate content, Ulva types are used with the aim of weight loss as low calorie diet. Especially in countries that have coasts to the seas, there are knowledges about the fact that algae are widely used in treatment of goitre and various kidney diseases and as an anthelmintic. For example, in South America, Ulva lactuca is used with the purpose to increase the resistance against goitre since it is rich in vitamin A [19,20]. Spirulina and Chlorella tablets are used to increase the body resistance. Antimicrobial effective Substances were obtained from Fucus serratus type. In addition, it is rich in iodine, so, it is used t treat goitre and against obezite which develops in relation to this illness [21]. Phenolic structured compounds such as phenol, flavonoid and tannin present in algae are responsible for the antioxidant activities and free radical repellent impact [22]. In the studies carried out with algae extracts, it was stated that the polyphenols existing in the extract exhibit antioxidant effect. In a study performed by using rats, it was established that red and green algae displayed protective effect against skin, breast and intestinal cancer, and that this effect increased the activities of phenolic compounds existing in algae extracts and of antioxidant enzymes in rat liver, and that this effect was realized by reducing the lipid oxidation.

Fikocolloids come first in significant usage fields of algae in pharmacy. Due to their hygroscopic properties, fikocolloids in structure of polysaccharides exhibit emulsifying, gelling, stabilizing,

suspending and thickening effects. It is known that fikocolloids affect the medicine absorbsion in the body as they have the properties to make colloids. Phyllophora nervosa which are present in the Black Sea is used as a source of fikocolloid in medicine and pharmacy. Aliquant obtained from algae are used as raw material or excipients in pharmaceutical industry. With this purpose, the usages of some active substances (insulin, antibiotics, hormones, vitamins etc.) are available in injectable or oral medication forms, in liquid solutions of oil and waxes, as filling substance in tablets, in providing homogenization and stabilization of oily creams, in producing emulsion, suspension, lotion, pomade, soap, shampoo, buffer, tooth paste and pastille, in covering the medication forms solved in intestines. Aliquants make the basic substance of plasters, dressings and bandages. Sagassum natans are primary algae which are used for preparing medication in emulsion forms in North America [19].

1.3. Usage of Algae in Other Industry Fields

1.3.1. Paper industry

They are used both in polishing the surface of papers and as a filling material, especially in parchment paper production, since they are waterproof and can prevent ink dispersion. Funori, obtained from red algae, is used as an adhesive for papers and clothes. It is similar to agar-agar except for containing sulphate group ester chemically [15]. Gelidialian red algae, except for Gelidyagilya family, contain rhizoidal philaments, and are processed to make poached pulps usable as raw material for paper production [23].

1.3.2. Rubber industry

They make the rubber achieve softness and fluidity after they are added to natural rubber. In paper and rubber industry, they are used to polish the surface of papers, and they are waterproof and prevent ink dispersion, thereby used as filling material. In addition, they facilitate the rubber to become softer and more fluid after being added to natural rubber [15, 18].

1.3.3. Paint industry

Besides fixation emulsion and stopping extreme fluidity and preventing the pigments to get more harm, they are used as paint concentrator and solvent as well. They are used in paint and textile industries as paint concentrator and solvents to fixate emulsion and to stop extreme fluidity and to prevent the pigments receive more harm [15,18].

1.3.4. Textile industry

They are used as solidifying before pattern print; and also they are used in artificial silk similar to natural silk by means of a special spray process. Aliquant, whose basic production raw material is brown algae, is used in printing and chemical finish processes and in fibre production in order to provide gelling, thickening and fixating [24]. Salt solutions of Aliquant making viscos liquids are used as sizing agent, thickener in chintz as sizing agent and finish substance [25]. In addition, fibre pulling process is applied to produce textile surfaces from Aliquant. The aliquant produced from algae are also used as separator thread in socks production, or in lace production, or in production of theatre curtains due to their non-flammable properties. Their most widely use is in injury treatment with sizing or paste mixture; and because of their advantageous properties, they are used in mixture form with other biopolymers. They are used as the basic material or in mixture form in medical textile applications for years with this biocompatible and biodegradable polymer; and the investigations related to new derivatives have been continuing [26].

1.3.5. Cosmetics industry

The solutions of Aliquant mucilage are used the basic substance in lotions and skin cleaning materials and in hair sprays and dyes and also in skin creams. They are used in soaps as foam booster and also they are added to tooth paste so that the chalk in it can be eliminated and added to shampoos as cleaner. In addition to all these, it is known that algae are used in leather industry and in packaging food [27]. It is also known that algal essences are used in skin care market and supporting renewing the tissues and reducing the wrinkles [28].

1.3.6. Solid, liquid oils and hydrocarbons

Most of algae contain solid and liquid oils similar the compounds of which are similar to vegetable oils. These oils can make 85% of the dry weights of algae under some conditions. This ratio is more than the lipids that land vegetables contain. In general, the average lipid contents of algae range from 20% to 40% of their dry weights. Solid and liquid oils obtained from algae have great usage potential in industry. Liquid oils algae produce have similarities with vegetable and fish oils. Due to these properties, they can be used instead of petroleum products. Direct extraction and refine of algae oils are two most effective methods to obtain oil from algae. This process is more effective than methane and ethanol production by fermenting algae biomass. Furthermore, the fermentation of the residue left after extraction is possible. Algae oils can be used instead of vegetables. In general, the hydrocarbons in algae available in them are 5% less than their dry weight. Until now, only has Botryococcus braunii been proved to produce 90% of hydrocarbon of its dry weight. It is thought that this algae species played important role in formation of petroleum reserves [18].

1.3.7. Usage of algae in aquacultures

Aquaculture is one of the rapidly developing branches of food production field. Algae production in aquaculture enterprises is very important. Fish, crustose and living or dead microalgae as food of commercially important molluscs are used in these cultures. Microalgae play very crucial role not only as food but also as carbon dioxide and oxygen balancer together with bacteria. The nutritional value of 11 Algin is important in aquaculture as well. While some larva cannot digest eukaryotic algae cell walls, while some others easily digest. However, since cell walls of prokaryotic cyano bacteria are digested easily, it is considered that the Usage of these group microalgae will increase [29].

2. CONCLUSION

Algae have extremely rich carbohydrate, protein and especially oil acid content. The algae whose nutritional value is high are the most vital source of food, vitamin and trace elements. At the same time, they provide basic pigments necessary for the development of colour in fish and other water creatures. The fact that the sea products in seas and fresh water are caught extremely and that the environmental pollution problems increase and that seas and inland waters have been polluted have led to reduction of organisms living in these places. Therefore, algae cultivation activities have gained speed. In plants where cultivation is carried out algae culture units are inevitable and the most significant stage of the system in larva feeding. Algae, the most important sources for living things of seas, are used as the source of energy, food, agriculture, cosmetics, medicine, pharmacy, nutritional stuff and mineral. It is also known that they are used in a number of branches of industry such as animal food, treatment of fertilizer wastes, dentistry, alcohol industry, drug industry, paper industry, rubber industry, paint industry, textile industry, solid, liquid oils and hydrocarbons and their usages in aquacultures and waste water treatment.

REFERENCES

[1] http://www.bilgiustam.com/algler-nedir-gorevleri-nelerdir. (cited 2018 May 20).

[2] Özdemir N, & Erkmen, J.Yenilenebilir biyoplastik üretiminde alglerin kullanımı. (The Usage of Algae in Renewable Plastic Production)Karadeniz Fen Bilimleri Dergsisi.2013; 3(8); 89-104.

[3] www.atlasakvaryum.com/index.php, (cited 2018 March5).

[4] Kargın Yılmaz N., Mersin için mikroalg üretiminin önemi, (The Importance of Algae Production for Mersin), Mersin Sempozyumu, 2008.

[5] http://www.algaeindustrymagazine.com/department/process. (cited 2018 February 21).

[6] Barry A, Wolfe A, English C, Ruddick C, Lambert D. National Algal Biofuels Technology Review, U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Bioenergy Technologies Office. Energy Efficiency and Renewable Energy, June 2016.

[7] Hoppe Heinz A, Levring T, Tanoka Y. Marine Algae in Pharmaceutical Science, Gruyter, Berlin, New York, 1979.

[8] Zeybek N, Zeybek U, Saygıner B. Farmasötik Botanik, Meta Basımevi, İzmir. 2003; 102-103.

[9] Mchugh DJ. A Guide to the Seaweed Industry, Fao Fishers, Rome, 2003.

[10] https://www.academia.edu/6884450/ALGLER%C4%B0N_EKOLOJ%C4%B0K_%C3%9 6 NEM%C4%B0. (cited 2018 January15).

[11] Guner H, Aysel V. A taxonomic study on some species Ulva (Chlorophyta) in Izmir Bay,Ege University Journal of Faculty of Science .1977; B1; 241-251.

[12] Haris R S. Vitamin K in Comprehensive Biochemistry Vol. 9: Pyrrole Pigments, Isoprenoid Compounds and Phenolic Plant Constituents. Florkin M, Stotz E (Eds.), Elsevier, New York. 1963; 192-198.

[13] Karakaş G, Erdal G, Erdal H, Esengün K. Tarıma Dayalı Enerji Politikası analizi ve Yenilenebilir Enerji Kaynağı Olarak Algler, (Analysis of Agriculture Based Energy Policy and Algae as Renewable Energy Sources), XI. Ulusal Tarım Ekonomisi Kongresi, Samsun 3-5 Eylül 2014.

[14] Ünver Alçay A, Bostan K, Dinçel E, Varlık C. Alglerin İnsan Gıdası olarak Kullanımı, (The Usage of Algae as Human Food), Aydın Gastronomy. 2017; 1 (1); 47-59.

[15] Oğur S. The nutritional value of dried algae and the usage as food, Ege Journal of Fisheries and Aquatic Sciences. 2016; 33(1); 67-79.

[16] http://w3.gazi.edu.tr/~tahir/alg/kullanim.htm. (cited 2018 May 20).

[17] Şen B, Koçer MAT, Alp MT, Sönmez F, YıldırımV. Alglerin atık su arıtımında kullanılması, (The Usage of Algae in Waste Water Treatment), XII. Ulusal Su Ürünleri Sempozyumu, 2003.

[18] Mikulewicz M, Chojnacka K. Algal Extracts in Dentistry, Book, Chapter 21, 2015.

[19] Demiriz T. Bazı alglerin antibakteriyal etkileri, (Antibacterail Effects of Some Algae), Yüksek Lisans Tezi, Ankara Üniversitesi, Fen Bilimleri Enstitüsü, Ankara, 2008.

[20] Aktar S, Cebe GE. General specifications, usıng areas of algae and their importance on pharmacy, Review article, J. Fac. Pharm, Ankara. 2010; 39 (3); 237-264.

[21] Serrano A, Palacios C, Roy G. Derivatives of gallic acid induce apoptosis in tumoral cell lines and inhibit lymphocyte proliferation, Archives of Biochemistry and Biophysics. 1998; 350; 49-54.

[22] Kumar K S, Rajagogol SV. Radical scavenging activity of green algal species, Journal of Pharmacy Research. 2011; 4; 723-725.

[23] Kuda T, Tsunekawa M, Goto H, Araki Y. Antioxidant properties of four edible algae harvested in the Noto Peninsula Japan, Journal of Food Composition Analyses.2005; 18, 625- 633.

[24] Seo YB, Lee YW, Lee GH, You HC. Red algae and their use in papermaking, Bioresource Technology. 2010;101; 2549–2553.

[25] http://www.hawkinswatts.com/documents/Alginate.pdf. (cited 2018 May 7)

[26] Özdemir Küçükçapraz D, Üçgülb İ, Elibüyük U. Alginates and Textile Fibres Applications, Anka E-Dergi Journal of Phoenix, Cilt 1/Sayı 1, 2016 .

[27] Seventekin N. Alginat Lifleri. Kimyasal Lifler, (Aliquant Fibres. Chemical Fibres), E.Ü. Tekstil ve Konfeksiyon Araştırma ve Uygulama Merkezi Yayını. 2003; Syf. 48-50.

[28] www.gazi.edu.tr/tahir/alg/ana.htm, [15 Ocak 2016]

[29] Kim SK, Chojnacka K. Marine Algae Extracts : Processes, Products, and Applications Edition: In book: 1Chapter, Vol. 2015.

[30] Özçiçek E, Can E, Yılmaz K, Seyhaneyıldız Can Ş. Usage of microalgae as a sustainable food source in aquaculture, Ege Journal of Fisheries and Aquatic Sciences, 2012; 34(3); 347-354 2017, Ankara, Turkey.