Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2012, 8 (3), 327-335

Alglerin Diesel Motorlarda Kullanım Olanakları

Mustafa GEZİCİ, Ahmet Konuralp ELİÇİN, Recai GÜRHAN

Ankara Üniversitesi Ziraat Fakültesi Tarım Makinaları Bölümü, Ankara
akelicin@agri.ankara.edu.tr

Received (Geliş Tarihi): 07.04.2011 Accepted (Kabul Tarihi): 17.05.2011

Özet: Dünyamız, enerjiye dayalı savaşların olduğu ve yenilerinin olabileceği ihtimalinin yükseldiği, iklimlerin değiştiği, petrol fiyatlarının arttığı, fosil kökenli yakıtların çok yakın bir gelecekte tükeneceği, dünyamızın küresel ısınma tehlikesiyle karşı karşıya kaldığı, atmosferimizin kirletilme hızının son derece arttığı, dolayısıyla sera etkisinin baş etmeni olan taşıt ve endüstriyel kaynaklı emisyonların azaltılması için devletlerin ortak çalışmaya çaba gösterdikleri bir sürecin içinden geçmektedir.

Geçmiş dönemde yapılan araştırmalar, dizel yakıtına göre sera etkisini %41 oranında azaltan, tarımda yeni fırsatlar sunduğundan dolayı hızla yayılan, bitkisel ve hayvansal yağ kökenli alkil esterleri ön plana çıkarması ve sağladığı avantajlar nedeniyle birçok ülkede yasal olarak vergiden muaf tutularak üretimi ve tüketimi arttırılan Biyodizel, maalesef ülkemizde üretimindeki ÖTV artışları, üreticileri sadece dağıtım firmalarına satış yapabilir hale getirmiştir. Dağıtım şirketlerinin alım zorunluluğunun olmaması ayrıca genel anlamda tarım maliyetlerinin yüksekliği gibi faktörler eklenmesiyle de biyodizel cazibesini kaybetmiş ve üniversitelerin ilgili bölümlerinin yaptıkları araştırmalar ölçüsünde ilerleyebilmiştir.

Son dönemlerde yapılan araştırmalar ise, ekosistemde CO_2/O_2 dönüştürücüsü ve biyokütlenin birinci üreticileri konumunda olan, mavi, kırmızı, yeşil vb. renklerde alg kültür sistemleri üzerine yoğunlaşmıştır. Algler üzerinde yapılan araştırmalar ise, yetiştiricilik ve yakıt olarak kullanılabilirliği başlıkları altında sürdürülmektedir.

Anahtar Kelimeler : Yenilenebilir enerji kaynakları, mikroalgler, biyodiezel, fotobiyoreaktöerler

The Possibilities of Using Algae for Diesel Engines

Abstract: The world is passing a process where wars based on energy are being experienced, climate is being changed, oil prices are going up, fossil fuel types are being exhausted, danger of global warming and the rate of atmospheric pollution is enormously increasing and thus countries showing common effort to decrease the emissions deriving from motor vehicles and industry that are the main sources of greenhouse effect.

The research studies in the past focusing on finding new energy sources were based on biodiesels which reduce the greenhouse effect by 41 % when compared with diesels. Due to this fact, many countries in the world have exempted biodiesel from taxes and encouraged their production and consumption. However, in Turkey, increase in production taxes, and because the producers can only sell their products to distribution firms, the attractiveness of biodiesel has decreasedtremendouslyandcouldonlybeendevelopedtothelimitsprovidedbythestudies of related departments of the universities.

The research studies focused on algae cultures which are blue, red, green in color and are transforming $CO_2$to O_2 in the ecosystem. There search studies on algae are implemented under two topics which are namely algae production and possibilities of using algae as fuel.

Keywords: Renewable energy sources, microalgae, biodiesels, photobioreactors.

INTRODUCTION

It is known that algae, which stand in the first step of food chain, are a valuable nutritive. Algae have a commercial value also in that they have the ability to create various chemical and biologic components. Vitamins, pigments, proteins, minerals, lipid and polysaccharides are basic products obtained from algae. The increase in the usage of algae in many fields has sped up the cultivation studies. Algae are simple, live, hygrophilous organisms which absorb light through photosynthesis and transform inorganic materials into organic. They range from small unicellular to complex multi-cellular forms.

Especially, the latest biotechnical and technical studies on microalgae seek to increase their use in food, agriculture, animal feed, environment and cosmetics. Therefore, it is important to base microalgae production upon some biotechnical basis because of its future contributions to the fields mentioned above.

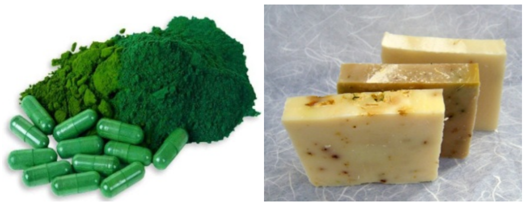

Figure 1. The use of Algae in medicine and cosmetics.

Although there have been many different classifications, algae can be classified simply in two categories as prokaryotic and eukaryotic. They are also separated into two as micro (one-year and unicellular, microscopic) and macro (perennial and cellulosic). Microalgae contain a higher rate of fat.

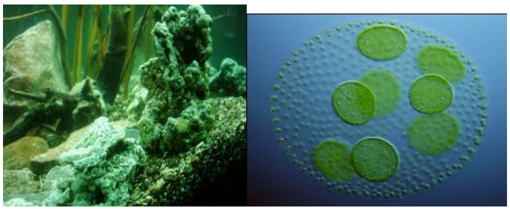

Figure 2. Eukaryotic and prokaryotic algae samples

Microalgae are known as Cholophyceae (green algae), Rhodophyceae (red algae), Cyanophyceae (blue green algae) and Pheophyceae (brown algae). Important pigments produced are chlorophyll a and b, Carotene, Astaxanthin, Fitosiyanin, xanthophyll, fito erythrosine. These pigments are frequently used in food, medicine, textile and cosmetics.

Production methods of Microalgae

In microalgae production, the purpose of mass-production is to obtain efficient product for a minimal cost. In high scale cultivation systems, effective usage of light, temperature, hydrodynamic balance in cultivation, providing the longevity of culture must be compared. The ideal development of any microalgae type occurs in cultivation environments in which distinctive conditions are met. Accordingly, while *Spirulina* achieves most growth in high Ph and bicarbonate density, *Chlorella* seeks highly nutritive environments and *Dunaliella salina* fosters in high salinity (Chisti, 2007).

Table 1. Fat content of some microalgae species

Microalgae	Fat Content (dry weight %)
Botrycoccus braunii	25-75
Chlorella sp.	28-32
Crypthecodinium cohnii	20
Cylindrotheca sp.	16-37
Dunaliella primolecta	23
Isochrysis sp.	25-33
Monallanthus salina	›20
Nannochloris sp.	20-35
Nannochloropsis sp.	31-68
Neochloris oleoabundans	35-54
Nitzschia sp.	54-47
Phaeodactylum tricornutum	20-30
Schizochytrium sp.	50-77
Tetraselmis sueica	15-23

Outdoor Production Systems;

It is possible to produce microalgae both indoors and outdoors. For outdoor production systems, natural ponds, pools and tanks produced out of various materials can be given as examples.

Figure 3. Outdoor production pools

Indoor Production Systems;

Indoor microalgae production systems can be named as small scale bags, tubular and flat-plate photo-bio-reactors. The most significant difference between outdoor and indoor systems is that outdoor production systems expose the microalgae cultivation to environmental effects directly.

Figure 4. Wide-Circular Production Pools (Algae global)

Botrycoccus braunii, *Chlorella* and *Spirulina* can be produced through mixture in open, shallow and wide-circular pools without any artificial blend. (Belay, 1997).

Table 2. Production Conditions of Microalgae.

Parameters	Limit Values	Optimum Conditions
Temperature (°C)	16-27	18-24
Salinity (g/ *l*)	12-40	20-24
Light Density (lux)	1000-10000	2500-5000
Light Exposure time (Day:Night h)		16:8 minimum 24:0 maximum
pH	7-9	8,2-8,7

Production in Wide Bags and Polyester Tanks;

The other systems used in aqua-cultivation are wide-bags and polyester tanks. In these tanks, production is conducted through the benefit of direct sun light (Kargın, 2002). The disadvantages of these systems are that the performance of production is not guaranteed and that the production cannot be assessed beforehand. The disadvantages of microalgae production in plastic bags are that the production is not continuous and that the system volume is increased relatively while it requires a huge amount of workmanship.

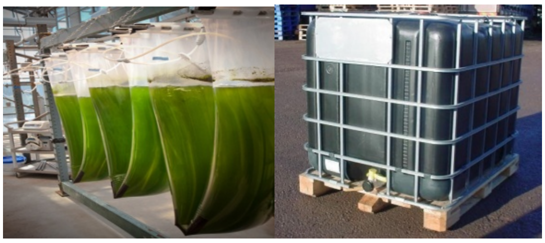

Figure5. The production in wide bags and polyester tanks.

Production in Photobioreactors;

The systems consisting of technical designs for microalgae production are called photobioreactors.

Outdoor photobioreactors are models, which are designed for microalgae production, depending on a continuous circulation system in transparent cylindrical tubes containing algae where there is abundant sun light.

Tubular Photobioreactors;

In tubular photobioreactors, the transparent tube shaped reactors can be developed in large scales. In the commercial production systems known as Bio-Fence, very robust or flexible transparent tubes or pipes are used. The production can also be extended by increasing the number and the diameters. The circulation of microalgae in bioreactors is achieved by a pump (Yılmaz, 2006). The outdoor tubes are constructed in vertical or horizontal position, or in specific angles.

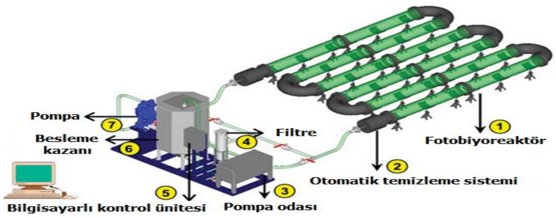

Figure 7. A Tubular Photobioreactor

In cleaning the microalgae accumulated on transparent or plastic tube surfaces, special beads are used. These beads are circulated with the algae, providing cleaning of the system. When a production in a larger scale is considered, the flow must be supported by increasing the length and the diameters of the tubes. This also requires a larger pump.

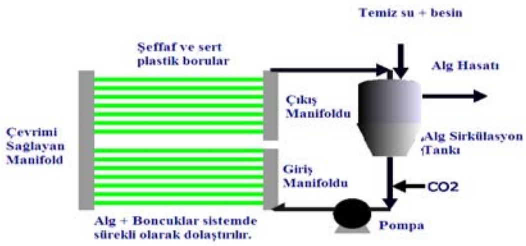

Figure 8. The working principle of a tubular photobioreactor.

Plate Shaped Photobioreactors;

Another type of photobioreactors is the plate shaped ones. The main principle of plate shaped photobioreactors or the purpose of designing narrow diameter pipe photobioreactors is providing effective use of sunlight by increasing surface width. The diameters of pipe photobioreactors is significantly decreased and plate shaped panels are preferred. All these designs involve glass or transparent plastics.

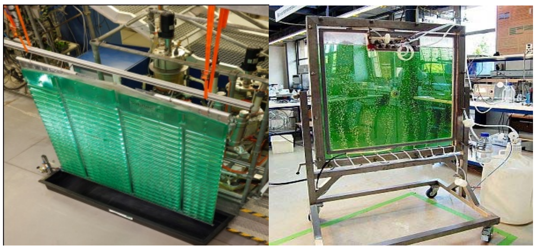

Figure 9. Transparent plastic flat plate photobioreactors and glass type flat plate photobioreactors.

Bio-coil Photobioreactors;

Apart from all the mentioned types, there are also photobioreactors with spiral tubes consisting of transparent narrow diameter plastic pipes that reel up, which form a coil. Bio-coil designs provide a balanced mixture and minimize the clinging algae on tube surfaces. The production process can easily be automated in that they are easy to move which indicates the fact that the system minimizes work force. However, this system is not suitable for all microalgae types.

Figure 10. Bio-coil photobioreactor samples.

The Comparison of Indoor and Outdoor Production Systems

Open pool systems vary greatly. The main reason of this is that these systems are economical, while indoor production systems require technology which is costly. However fewer kinds of microalgae can be cultivated outdoors.

Also in outdoor environment, the cultivation is susceptible to contamination. The losses resulting from continuous evaporation, CO_2 emission and contamination risk are the other disadvantages of outdoor systems (Naz and Gökçek, 2006).

Table 3. The comparison of open and closed systems

	Outdoor Systems	Indoor Systems
Contamination Risk	Very High	Low
Space Requirement	High	Low
Water Loss	Very High	None
CO_2 Loss	High	None
Variety of Types	Limited	All kinds
Standardization	Not possible	Possible
Dependence on Weather Conditions	No Production in Rain	No dependence
Production Concentration	Low 0,1-0,2 g/l	High 2-8 g/l
Effectiveness	Low	High

Considering indoor systems, it is quite costly to maintain and install. However these systems should be applied for only one kind. Indoor systems have many advantages such as preventing contamination, effective usage of light, high effectiveness, controlling temperature and using the sunlight from reactors installed outdoors. In indoor reactors, it is easy to control the cultivation environment as well as the product is satisfactory in quality and effectiveness.

Throughout The World

Microalgae have been observed in island countries with great interest so far because of their opportunity to be used as a nutritive. As a result, they have a long historical past. Nowadays, they are being used as a raw material for some products in many fields in industry in Europe and USA. The USA took the lead by its recent studies in microalgae production. Microalgae have attracted so much attention of the American government that in 2010 American Ministry of Energy accepted to give 24 million $ to 3 different research teams looking for ways to commercialize algae based bio-fuel.

Figure 11. Algae production company Algeponics, The USA (Algae Magazine Industry)

When microalgae production shares are considered, the USA is the leading country with 47%. The USA uses the most of its produced microalgae in medication and cosmetics while Bio-fuel production has an insignificant share. China is the second with a production rate of 21%. Microalgae produced in

China are used in food industry only. Australia and New Zealand follow the USA and Chine with a ratio of 14%. Contrary to the two leaders, New Zealand is the only country that uses microalgae in bio-fuel effectively.

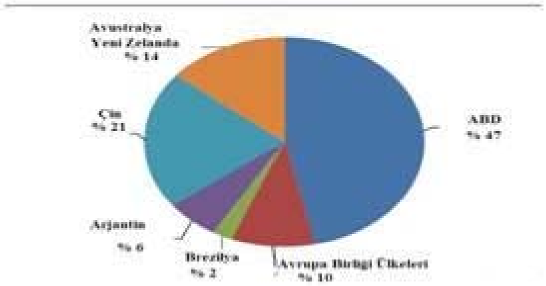

Figure 12. Microalgae production share according to countries (2010) (FAO)

Green Fuel Tech Aurora Biofuels Gmbh, Arizona, The USA's microalgae production in bags test has reached high costs.

Figure 13. GreenFuel TechAurora BiofuelsGmbh, Arizona, Algae production facility (Algae Magazine Industry)

Figure 14. Synthetic Genomics, Spain, A microalgae facility of Gmbh (Algae global)

Figure 15. Algaepower Gmbh Manhattan , A newly installed photobioreactor in the USA

The only purpose of companies installing microalgae facilities is producing bio-fuel, although they prove to be in research and development phase at the moment. It is emphasized that fuel production with microalgae is not a difficult task at all.

Figure 16. Bio-fuel produced by a company called Aquaflow (Algae Magazine Industry)

It is not, however, as easy as it is thought to commercialize this project which has been studied for last 20 years. Even though many countries are trying to obtain bio-fuel out of microalgae, so far only a company in New Zealand has been able to produce an amount of fuel enough to run a car.

Figure 17. The automobile run by the company called Aquaflow (Algae Magazine Industry)

Situation in Turkey

One of the few establishments operating on this subject in Turkey is Ege Biyoteknoloji. Ege Biyoteknoloji A.Ş., receiving support from Tübitak, states that 40% of the project is funded by Tübitak and that they are working on microalgae with the highest fat effectiveness. Bio-engineering department of Ege University, which took the project to Ege Biyoteknoloji A.Ş., has participated in many projects involving microalgae. High scale researches are being made in microalgae laboratories of the establishment and there exists a collection of about 30 different types.

Ege Biyoteknoloji A.Ş., which is the private sector company to support the project, is producing bio-fuel in its facilities in Bergama; in addition, the foundation is capable of conducting analyses in order to determine whether the obtained fuel is compatible to the standards.

One of the establishments supporting the project, Dokuz Eylül Üniversitesi Çevre Araştırma ve Uygulama Merkezi (Dokuz Eylül University Environmental Research and Application Center) (ÇEVMER) is due to supply the refined waste water to be used for microalgae production and in laboratories; they will make the necessary chemical and physical analysis to determine the environment created as a result of the supplied water and microalgae harvest. Moreover, the foundation will contribute to the fat extraction and bio-fuel production process.

Obtaining Fat out of Microalgae

First of all, a microalgae cell count is conducted to determine the number of mature microalgae cells. Microalgae reaching an adequate cell number (which depends on the type of microalgae) are moved into another tank before the "stress" process. A high amount of catalyst is released from nutritive tank in order to expose the algae to stress. Specific parameters are to be modified unless the catalyst is not applied. Stress process forces the microalgae to produce fat quickly before the extraction process. After the stress process, extraction begins. The first phase of fat extraction is the dehydration of microalgae in Lab-50 Microalgae Harvest Unit. With the air inside Lab-50 Microalgae Harvest Unit and a belt rotating continually, water is removed from microalgae.

Figure 18. Lab – 50 Microalgae harvest unit process schematics (Algae Industry Magazine)

Microalgae retrieved out of Lab – 50 microalgae harvest unit are completely dehydrated. Dehydrated microalgae are also called scales. These scales are sent to pressure machines to extract fat. Custom fat extraction machines are present in many companies producing in small scales. In enterprises without these custom fat extraction machines, many different fat extractors are used also.

Figure 19. Microalgae in scale form (Algae global)

After extraction, microalgae are handed back as an algae pile from the lower part of the machine. The fat is taken into a closed container. Microalgae piles can be reused as ethanol, fertilizer and animal feed. They are used as pellet animal feed especially in Europe (Hossain et al. 2008).

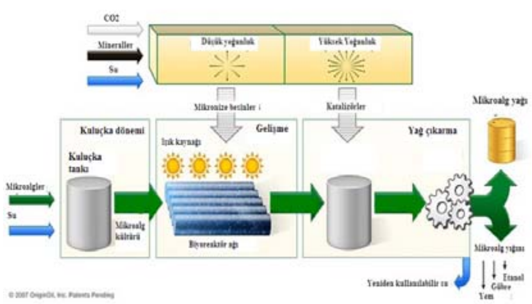

Figure 20. Microalgae production phases and fat extraction schematics (Algalbiyodizel)

Fuel Specifications of Microalgae

Microalgae have a high energy potential thanks to the fatty acids which consist more than 80% of their own amount such as oleic acid (C18:1) and plamitoleic acid (C 16:1). Because of this, It is highly feasible to transform microalgae into fuel.

Table 4. Fatty acid compositions of Micro-organisms (Respectively; palmitic, palmitoleic ,stearic, oleic, linoleic, linolenic)(Meng et al., 2009)

	16:0	16:1	18:0	18:1	18:2	18:3
Microalgae	12-21	55-57	1-2	58-60	4-20	14-30
Ferment	11-37	1-6	1-10	28-66	3-24	1-3
Fungi	7-23	1-6	2-6	19-81	8-40	4-42
Bacteria	8-10	10-11	11-12	25-28	14-17	-

Table 5. Comparison of some biodiesel sources (Eliçin et al., 2009)

Product	**Fat Production (l/ha)**
Corn	172
Soy	446
Canola	1,190
Jatropha	1,892
Coco Nut	2,689
Palm	5,950
Microalgae (%30 fat)	58,700
Microalgae (%70 fat)	136,900

Fuel Production Methods using Microalgae

For the methods of transforming microalgae into biodiesel; Pyrolysis, gasification and transesterification methods can be given as examples.

Pyrolysis Method

This is the method of transformation in which the biomass is dissolved into liquid (bio-petrol), solid (charcoal) and gas state. Pyrolysis is the basic chemical process used to change the biomass into a more useful fuel. Pyrolysis is the most effective process for biomass transformation, it can also compete with non-renewable fossil fuels and in the end it can replace them completely. The effectiveness of biomass in transforming into raw petrol reaches 70% through a rapid Pyrolysis.

Figure 21. Pyrolysis Device

Gasification method

"Gasification" is the process in which a secondary gas fuel is obtained predominantly during Pyrolysis. Gasification transforms the bio-mass into a flammable gas consisting of carbon monoxide, hydrogen and methane. The obtained gas is more flexible than the original solid biomass; it can be combusted to produce heat or vapor or it can be used in gas turbines to produce electricity.

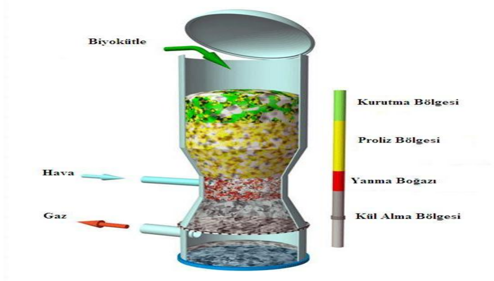

Figure 22. Gasification process schematics

Transesterification Method

Transesterification method is the process of transforming fats into esters in reaction with alcohol by also using a catalyst. This method is the most useful one in reducing the viscosity (Eliçin et al., 2007). For instance, in a transesterification process on castor oil, while the viscosity of raw castor oil is 1100 Redwood second at 100 ^{o}F, after the transesterification it is reduced to 74 Redwood Second at the same heat (Agra et al., 1996). Transesterification process today is so widely common that in many countries facilities, the same size as oil refineries, are being built.

Figure 23. Transesterification facility

Transesterification is a balanced reaction in which the reaction occurs by completely mixing the catalyst. The presence of the catalyst has an accelerating effect on balancing the reaction. In order to obtain a considerable amount of ester however, also a high amount of alcohol must be used. In transesterification, a triglyceride and a type of alcohol must be put in the reaction with a powerful acid or the basic catalyst so that we can obtain acidified alkyl ester and glycerin. Considering the whole process, the reaction proves to be a three-phase two-way chain reaction yielding diglyceride and monoglyceride.

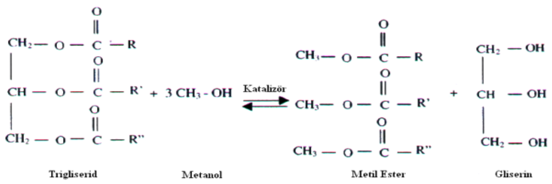

Figure 24. Transesterification Mechanism

Similarly, the fat obtained from microalgae turns into fatty acid methyl esters and glycerin in the presence of a catalyst (acidic, alkaline and enzyme) and an alcohol (ethanol, methanol). The variables affecting microalgae fat effectiveness during transesterification are the quality of algae fat, molar rate of alcohol to microalgae fat, reaction temperature, reaction time, the type of catalyst and amount.

The amount of change in the end of the reaction can be found through the analysis of upper phase in gas chromatography or thin plate chromatography (Eliçin et al.,2007).

Figure 25. Gas chromatography devices

RESULTS AND DISCUSSION

It is possible to obtain biodiesel out of microalgae and yet there are no differences in production from the methods used with vegetable oils and fat. Biodiesel production based on microalgae considerably competes with fossil fuels. In economical microalgae production, biology and genetic engineering play a significant role. Engineering designs on photobioreactors and increasing the use of bio-refineries will help decreasing the costs in production.

In order to mass-produce microalgae needed for biodiesel production, tubular photo-bio-reactors are used more efficiently than open-pool systems. Photo-bio-reactors keep the environmental conditions under control and provide a standard output. Today neither bio-ethanol nor biodiesel can rival fossil fuels. Only the low cost and development in the quality help competing.

In the future, the development of micro-organisms containing a considerable fat rate including algae, development in the biodiesel production process and the results of the studies made in this field will increase the use of algae in energy production.

REFERENCES

Agra, I.B.,Warnijati, S. and Wiratni, F. 1996. Two steps ethanolysis of castor oil using sulfiric acid as catalyst to producer motor oil. World Renewable Energy Congress, p., 1025, June 15 – 21, Colorado.

Belay, A., 1997. Mass Culture of Spirulina Outdoors. The Earthrise Farms Experience. In: Vonshak, A.(eds.), Spirulina platensis (Arthrospia): Physiology, cell – biology and biotecnology. Taylor and Francis, London; 131 – 158.

Chisti, Y. 2007.Biodiesel From Microalgae. Biotechnology Advances. 25 : 294 – 306.

Eliçin,A.K., K.Saçılık, ve D. Erdoğan, 2007.Haşhaş Yağı Esterlerinin Bir Diesel Motorda Kullanım Olanaklarının Belirlenmesi. Tarımsal Mekanizasyon 24. Ulusal Kongresi Bildiri Kitabı, 5-6 Eylül, Kahramanmaraş

Eliçin,A.K., A.Kılıçkan, ve A.O.Avcıoğlu, 2009.Mikroalglerden Biyodizel Üretimi. Tarımsal Mekanizasyon 25. Ulusal Kongresi Bildiri Kitabı, s:273 -278, Ekim, Isparta

Kargın, H., 2002. Mikroalg – Rotifer Kültür Sistemleri Tasarımı, Yardımcı Ders Kitabı, Su ürünleri Fakültesi Yayınları No:3; ISBN 975-6900-08-3; 15 – 16.

Meng, Xin, J. Yang, X. Xu, L. Zhang, Q. Nie and M. Xian, 2009. Biodiesel Production from Oleaginous Microorganisms. Renewable Energy. 34: (2009), 1-5.

Naz, M. Ve K. Gökçek, 2006. Fotobiyoreaktörler: Fototropik Mikroorganizmalar için Alternatif Üretim Sistemleri. Ulusal Su Günleri 2004, 6-8 Ekim 2004, İzmir.

Sharif Hossain, A.B.M and A., Salleh, 2008. Biodiesel Fuel Production from Algae as Renewable Energy. American Journal of Biochemistry and Biotechnology. 4 (3) : 250 – 254.

Yılmaz, H.K., 2006. Mikroalg Üretimi için Fotobiyoreaktör Tasarımları. E.Ü. Su Ürünleri Dergisi. 23 (1/2) : 327-332

Algalbiyodizel – Biyodizel web sitesi (http://www.algalbiyodizel.com/post/Alg-yagc4b1-ekstraksiyonu.aspx) Erişim tarihi: 17.01.2011

Alg magazin – Alternatif yakıtlar web sitesi (http://www.algaeindustrymagazine.com/department/a-i-m-interviews/) Erişim tarihi: 12.01.2011

Algae global – Alglerle ilgili son gelişmeler (http://www.algaeglobal.com/hinben%20algae%20oil%20press.htm) Erişim tarihi : 20.01.2011

FAO – Alg üretim istatistikleri (http://www.fao.org/corp/statistics/en/) Erişim tarihi: 12.01.2011