Araştırma Makalesi
(Research Article)

Ege Üniv. Ziraat Fak. Derg., 2017, 54 (1):9-16
ISSN 1018 – 8851

A. Engin ÖZÇELİK

Investigation of The Effects of Safflower Biodiesel Blends with Eurodiesel Fuel on Engine Performance and Emissions in Common-Rail Diesel Engine

Common-Rail Dizel Motorda Aspir Biyodizeli ile Eurodizel Karışımlarının Motor Performansı ve Emisyonlarına Etkisinin İncelenmesi

Selcuk University, Technology Faculty, Mechanical Engineering, 42030, Konya / Turkey
corresponding author: eozcelik@selcuk.edu.tr

Alınış (Received): 21.06.2016 Kabul tarihi (Accepted): 27.07.2016

Key Words:

Biodiesel, safflower, common-rail, engine performance, emissions

ABSTRACT

In this study, produced by the transesterification method safflower methyl ester material is used. Trials, 4-stroke, 4-cylinder, with engine test was conducted in a water-cooled engine has common rail fuel system. And B2 (2% v safflower biodiesel - 98% Eurodiesel), B10 and B50 biodiesel-Eurodiesel fuel blends have been accepted as the reference fuel. The results are given in comparatively. The main factor of the observed changes in engine performance when biodiesel is used is the low calorific value fuel compared to Eurodiesel fuel. There is an increase in engine power as a result of the improvement of the fuel oxidation of oxygen in the body of biodiesel in the partial load conditions. While emission changes are taking place in accordance with the terms of reference fuel emission produced by alternative fuels, it has constructed the partial differences in the rate of increase and decrease. Due to the fact that the engine used in the experiments keeps the fuel under a very high pressure, HC emissions are lower than the other engines.

Anahtar Sözcükler:

Biyodizel, aspir, common-rail, motor performansı, emisyonlar

ÖZET

Bu çalışmada transesterifikasyon yöntemi ile Aspir yağından biyodizel üretilmiştir. Çalışmada kullanılan deney motoru, common-rail yakıt sistemine sahip, su soğutmalı ve 4-silindirli 4 zamanlı diesel motorudur. Üretilen biyodizelden B2 (%2 Aspir biyodizeli, %98 Eurodizel), B10 ve B50 karışımları hazırlanmış, referans yakıt olarak da Eurodizel kabul edilmiş ve sonuçlar karşılaştırmalı olarak verilmiştir. Biyodizel kullanıldığında motor performansında gözlenen değişikliklerde başlıca etken yakıtın ısıl değerinin Eurodizele göre düşük olmasıdır. Kısmi yük şartlarında biyodizelin bünyesindeki oksijenin yakıtın oksidasyonunu iyileştirmesi sonucu motor gücünde artış olmuştur. Emisyon değişimleri alternatif yakıtların üretmiş olduğu emisyonlar bakımından referans yakıt ile uyum içerisinde yer alırken artma ve azalma oranlarında kısmı farklılıklar oluşturmaktadır. Deneylerde kullanılan motorun yakıtı çok yüksek basınç altında tutmasından dolayı HC emisyonları diğer motorlara göre düşük çıkmıştır. Biyodizel kullanımında, yakıt içeriğinde oksijen bulunması sebebi ile egzoz gazlarındaki NOx miktarında artış olmuştur. Yapılan bu çalışmada da egzoz gazları içindeki NOx miktarının en fazla B100 yakıtında olduğu görülmüştür.

INTRODUCTION

Knowing and predicting the numerical position and the future of these sources within the available resources have a different significance while renewable energy technologies are developing. Creating a database on energy and doing script work is works difficult and have common effects. Each country sees its place in the works done for the world as well as the works done on the basis of the countries. (Acaroğlu, 2001; Pourzolfaghar et al, 2016).

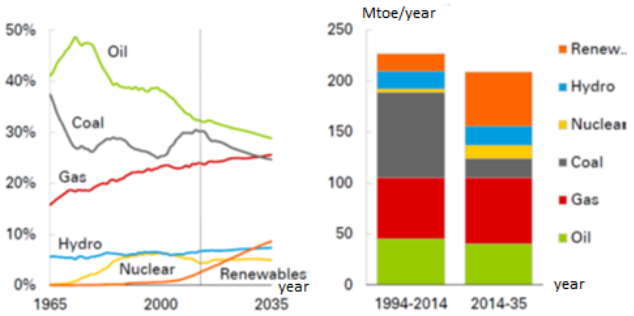

Figure 1. Primary energy development in the World (BP, 2015; BP, 2016; IEA; 2010; IEA, 2015a; IEA, 2015b; IEA, 2015c; IEA, 2013)

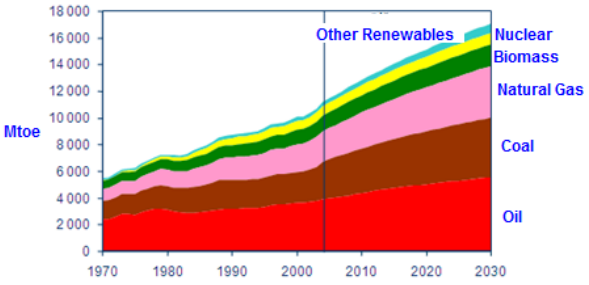

Figure 2. Reference Scenario for the World Primary Energy Demand (BP, 2015; BP, 2016; IEA; 2010; IEA, 2015a; IEA, 2015b; IEA, 2015c; IEA, 2013)

Many countries encourages the efforts made on reducing addiction to the imported fuels (particularly fossil fuels) while they support the most convenient and low-cost business research of local resources to meet the growing energy demand in parallel with the developments in their economy and industry (Sajjad,, 2016; Saluja 2016).

The rapid increase in the welfare of humanity was made possible by the use of fossil fuels but the development of the industry, and to bring with it air pollution caused again this fuel causes the development of the industry to bring with it the air and environmental pollution (Mihaela et al, 2013; Mucino et al, 2014). Today known as the most important environmental problems of the world, global warming caused by the greenhouse effect, primarily resulting from combustion emissions, is a result of harmful emissions as SOx and NOx (Agarwal and Rajamanoharan, 2009). The adverse effects of fossil fuels on the environment and human health have been proven in recent years. The most important issue is that the fossil fuels are on the point of exhausting in addition to the positive and negative effects of its use (Pieprzyk et al, 2009; İlkılıç et al, 2011; Aydın, 2016).

Biodiesel's strategic location can not be ignored. Biodiesel can be produced from plant, animal and waste oil. Biodiesel can be used in diesel engines without any modification as of 100% and in a mixture ratio with diesel fuel (Özesen and Çanakçı, 2008). Biodiesel doesn't include sulfur, aromatic hydrocarbons, metals and crude oil negatively affecting the formation of emissions and diesel engine combustion efficiency. In this respect it is considered to have a more ecological structure according to the diesel fuel (Thangaraja et al, 2016; Öğüt et al, 2011).

Today, biodiesel production gains a commercial size and its production quantities are now growing rapidly. The annual increase in production of biodiesel in the world is seen in Figure 3.

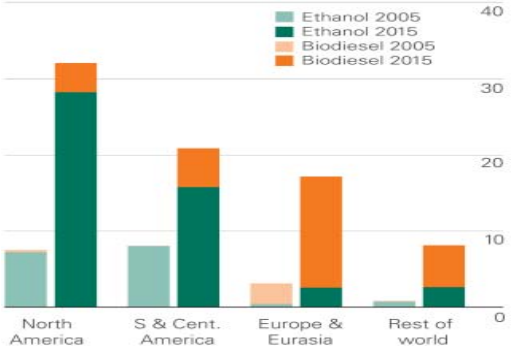

Figure 3: The production of biodiesel in the world (BP, 2016)

Safflower (*Carthamus tinctorius L.*)

Safflower plants from the Composite family (*Carthamus tinctorius L.*) (2n = 24) is a cultural plant began to be taken 3000 years ago in the Middle East. Safflower is a long day of summer oilseed crop that contains oleic and linoleic oil between %30-%45 in its

60-120 cm long seed and with its root 1.5-2.0 meters in depth; with its yellow, red and orange flowers; and with its thorny and thornless structure. Its oil used in the production of biodiesel is also used in meals, frying and salads. It's for one year, drought-resistant and its life is 110-140 days. The wild forms of the plant whose origin is Anatolia can be found in every part of our country. The production of safflower plant the most suitable plant in narrowing its fallow field is increasing in recent years. Production inputs are very low, there is no marketing problem and it easily finds buyers produced by contract. It is a plant that will shut down our oil and energy deficit by processing to cooking oil and biodiesel. Instruments used for the production of wheat can be used without the need for additional investment. Its oil with very high quality lowers cholesterol, diabetes and debilitating. Its flowers are consumed as bee forage and tea; its straw and bagasse are consumed as animal feed (Babaoğlu, 2007; Thomas et al, 2012; Eryılmaz 2016).

Figure 4. Safflower varieties (Özçelik, 2011)

Because of the increasing oil deficit in our country day by day, Anatolia Agricultural Research Institute Safflower works under the Ministry of Agriculture and Rural Affairs have resumed due to the search of alternative crops in the decreasing field of beet. A kind called Remzibey-05 was registered in 2005. Yenice and Dinçer were thornless; Remzibey-05 is thorny and the characteristics of these types of Safflower were shown in Table 1. (Özçelik., 2011). Honey type was introduced to public opinion by being developed within the Anatolia Agricultural Research Institute and by holding a press conference in May 2011. These trials continuing 5 years were introduced to public opinion by Ayaz type Bahri Daşdaş International Agricultural Research in 2012. Linas type is also a kind of safflower registered by the Institute of Trakya Agricultural Research in 2013. Characteristics of some of safflower species were given in Table 1.

Table1. Safflower varieties in our country

Types	Yenice	Dinçer	Balcı	Remzibey-05	Ayaz	Linas
Prickliness	Thorny	Thornless	Thorny	Thorny	Low Thorny	Thorny
Flower clour	Red	Orenge	Yellow	Yellow	Red	Yellow-Orange
Plany tall (cm)	100-120	90-110	55-70	60-80	100-120	85-90
Grain clour	White	White	Cream	White	White	Cream
Oil rate (%)	24-25	25-28	38-40	35-40	22-25	37-38

Despite the recognition for many years in our country, its agricultural practices are not known enough. However, its growing is very easy as in the cultivation of wheat and barley. Deep, efficient, good drainage, high water holding capacity, pH 5-7 soils are better suited to the soil. The yield in the soil no deeper than 30 cm, having foot stone in light gray and White and very high sandy and cancerous lands decreases even if the products are received. The degree of salt tolerance is as in barley (Weiss, 2000; Öztürk et al, 2010).

The most important entries in safflower agriculture emerge as weed control and fertilization. The weed population should be decreased by disinfestation before planting because the weeds are effective mostly

during seedling stage. The amount of fertilizer in Safflower agriculture varies according to the climate and soil conditions. Although there wasn't any important illness and damage in Safflower agriculture in our country, Safflower rust was observed.in wet and regions last year (Puccinia carthami) in the past years (Shahrokhnia and Sepaskhah, 2016; Öğüt, 2007).

In this study, the biodiesel produced by transesterification method from safflower oil is used. In a four-stroke, common-rail fuel system, and water cooled, in an engine 4-cylinder volume engine, 2% (B2), 10% (B10), 50% (B50) biodiesel - diesel fuel blends have been accepted as the reference fuel. The results are given in comparatively.

MATERIAL and METHODS

Biodiesel produced from varieties Remzibey used in this study. By using this biodiesel and diesel, B2 (2% v safflower biodiesel - 98% Eurodiesel), B10 and B50 fuel blends were prepared. Trials were made on the engine with this prepared mixture. The test arrangement used in this study is shown in Figure 5. Experiment engine is a diesel engine with 4-cylinder, having the common-rail type fuel system, over-loading and intercooled engine. Technical characteristics of the engine are given in Table 2. Technical properties of the engine dynamometer and exhaust emission apparatus used in this study are given in Table 3 and Table 4.

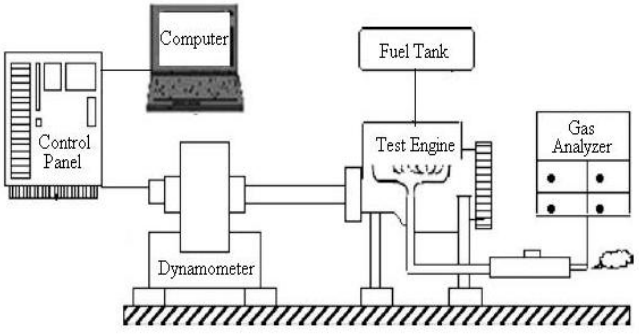

Figure 5.Experimental set up

Table 2.Technical characteristics of the engine used in the study

Engine	**1.9 Multijet**
Number of cylinders and layout	4, a single row of the front transverse
Cubic capacity (cc)	1910
Compression ratio	5.18: 1
Maximum power hp - d / d	105 - 4000
Maximum torque Nm (kgm) - rpm	200 - 1750
Fuel	diesel
Fuel supply	Electronically controlled Common Rail type
	MultiJet direct injection, turbocharger and intercooler
Ignition	compressional
Bore x Stroke (mm)	82 x 90.4

Table 3. Technical specifications of the engine dynamometer

Model	BT-190 FR
Capacity	100 kW
Maximum speed	6000 rpm
Maximum torque	750 Nm

Table 4.The specifications of the exhaust emission apparatus used in this study

Measuring Range	Unit	Value
CO	%	0-9.99
CO_2	%	0-19.99
HC	ppm	0-2500
Λ	%	0-1.99
O_2	%	0-20.8
NOx	ppm	0-2000

Experiments have been carried out at different engine speeds in full throttle position. Before starting the measurements, the engine was heated to the operating temperature. Experiments began after closing and opening the engine fan two times.

EXPERİMENT RESULTS and DISCUSSION

The diesel used in the four-cylinder diesel engine with Common-rail fuel system and its changes of the power rate of safflower biodiesel fuel mixture depending on the power speed of the engine is shown in Figure 6. Effective power increases depending on the engine speed increases with biodiesel fuel and Eurodiesel fuel characteristically. Maximum engine power in all fuels was obtained as 3000 rpm. With an overview, Eurodiesel fuel in all engine power and the values of the engine power in B2, B10 and B50 are obtained close to each other. Power difference obtained between Eurodiesel fuel and B2, B10 and B50 fuels at high speeds is increasing even if just little.

Changes of specified torque according to engine speed are given in Figure 7. Considering the average values, maximum torque value 2000 rpm is seen approximately in Eurodiesel fuel. Due to the low calorific value owned by biodiesel, lower values emerge in torque as in the engine power as shown in Figure. But on the contrary of this case, those values can show the improvement of the combustion characteristics of the oxygen content of biodiesel fuel and keeping the performance characteristics of the engine at a reasonable level.

Changes in specific fuel consumption depending on the engine speed are given Figure 8. When all the fuels were examined, the lowest specific fuel consumption, as shown in figure is determined in Eurodiesel fuel 2500 rpm. The lowest specific fuel consumption value in other fuels is determined in this speed. The reason of high rise of specific fuel value of biodiesel mixtures is the lowness of lower heating value compared to Eurodiesel fuel.

CO has an adverse effect on human health such as fatigue, the decrease in working efficiency, headache, dizziness, dyspnea, loss of consciousness (lethal when reaches the amount of the 0.3% threshold in air) (Öğüt, 2007). CO values of fuels depending on the engine speed is given in Figure 9. According to the results, CO values of safflower biodiesel is low because of complete combustion as to B2, B10 and eurodiesel fuel. This means that the combustion efficiency in the biodiesel mixtures is higher.

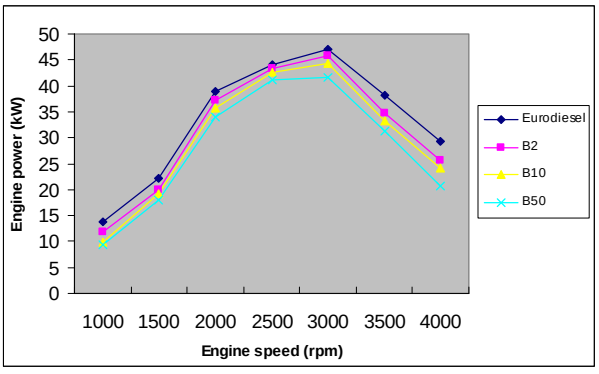

Figure 6. Variation of engine power with engine speed

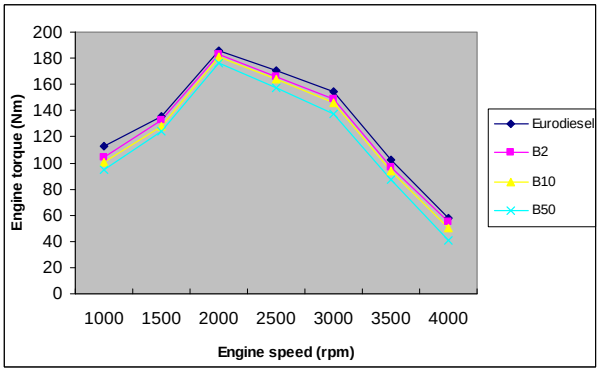

Figure 7. Variation of engine torque with engine speed

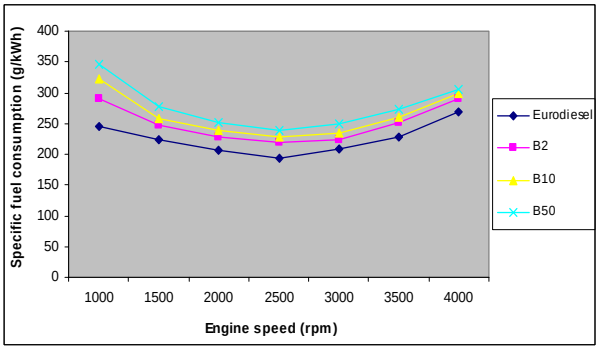

Figure 8. Relation between the specific fuel consumption with the engine speed

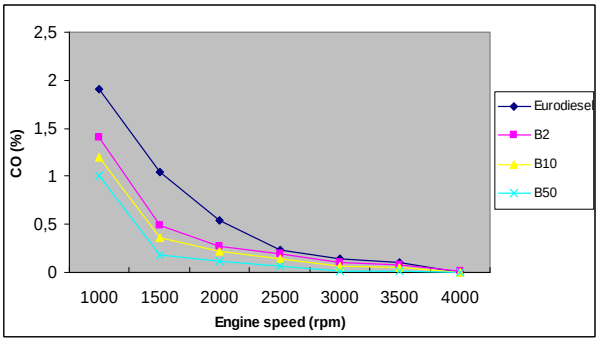

Figure 9. CO emissions

CO_2 values of fuel depending on the engine speed are given in Figure 10. According to the results, CO_2 value of Eurodiesel fuel is low compared to B2, B10 and B50 fuel values. CO_2 that arises from the combustion of renewable energy origin fuel is maintained by plants. Plants spare CO_2 for the carbon and oxygen. Oxygen is released back to the atmosphere. Renewable energy use provides the formation of the natural balance in CO_2 emissions.

HC values of fuel depending on the engine speed are given in Figure 11. Considering the average value, HC values of B2, B10 and B50 fuels are low by % 50 compared to diesel fuel. The reason of occurrence of hydrocarbon among unburned products is the oxidation and semi oxidation of the fuel due to not coming to the ignition temperature and being insufficient of fuel. For this reason, it is more important to use biodiesel anf its mixtures especially in common-rail-type engines in terms of emissions.

The O_2 values of fuels depending on the engine speed are given in Figure 12. O_2 value of B50 fuel seems to be highes according to the results. O_2 value of B2 and B10 fuels is high compared to Eurodiesel fuel. The reason of high value of oxygen compared to eurodiesel fuel is that there is O_2 inside the biodiesel.

The NO_X value of the fuels depending on the engine speed are given in Figure 13. According to the results, the NO_X values of the Eurodiesel fuel are lower than B2, B10 and B50 fuels. The reason for this is due to the fact that vegetable oil contains oxygen in the ratio of 11%. High heat that occured as a result of combustion of fuel in the engine, the nitrogen oxides have occured by nitrogen in the air combining with oxygen. Also, as combustion duration in the flammable fuels, there has been an increase in NO_X.

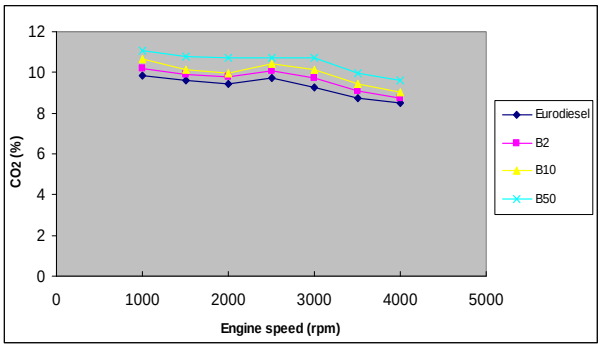

Figure 10. CO_2 emissions

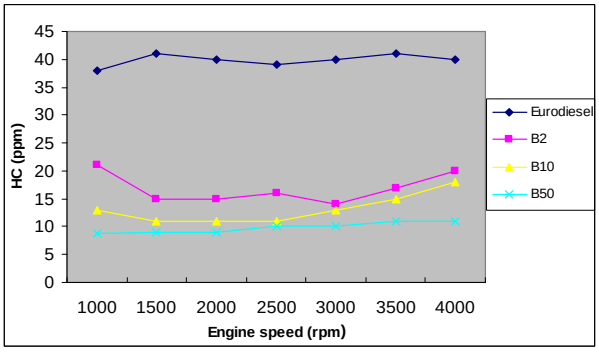

Figure 11. HC emissions

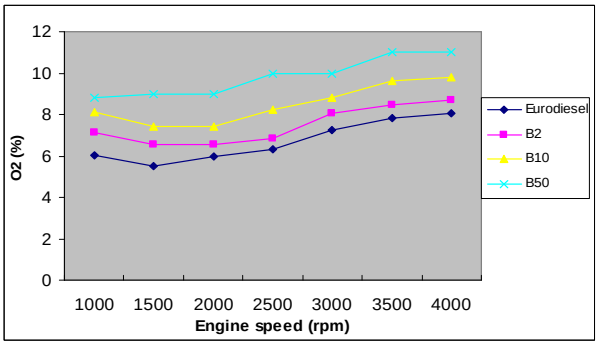

Figure 12. O2 emissions

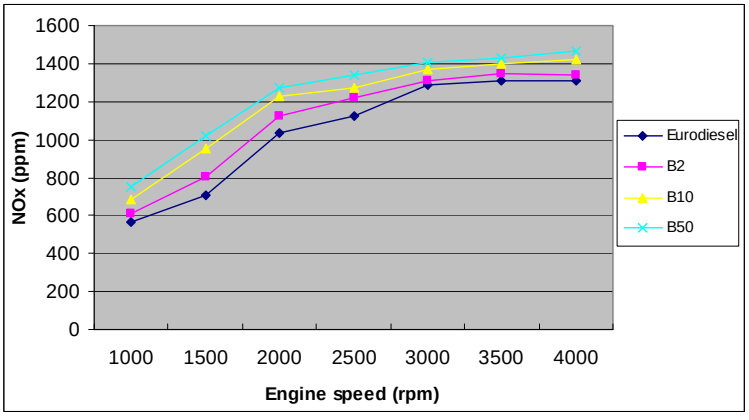

Figure 13. NO_x emissions

CONCLUSIONS

In this study, biodiesel has been obtained from safflower oil and diesel fuel by the transesterification method. Biodiesel fuel has been used separately without any alteration in Eurodiesel engines respectively. The engine performance and emission characteristics of this fuels have been subjected to tests at full load and different engine speeds. According to the data, engine performance and emission variation curves of each fuel have been obtained and these curves have been compared with each other.

The main factor of the observed changes in engine performance when biodiesel is used is the low calorific value fuel compared to Eurodiesel fuel. There is an increase in engine power as a result of the improvement of the fuel oxidation of oxygen in the body of biodiesel in the partial load conditions. While emission changes are taking place in accordance with the terms of reference fuel emission produced by alternative fuels, it has constructed the partial differences in the rate of increase and decrease. Due to the fact that the engine used in the experiments keep the fuel under a very high pressure, HC emissions are lower than the other motors.

Producing biodiesel from Safflower oil and using the produced biodiesel as an alternative fuel for diesel engines have a good effect on reducing external dependence of energy. Besides, it contributes to the formation of new business areas. As a result, using safflower oil as an alternative fuel for diesel engines has a positive effect in ecologic and economic areas.

ACKNOWLEDGEMENT

This work is supported by the Coordinatorship of Selcuk University's Scientific Research Projects.

REFERENCES

Acaroğlu, M., Oğuz, H. and Öğüt, H., 2001, An Investigation On The Use Of Rape Seed Oil In Agricultural Tractors As In Engine Oil. Energy Sources, Volume 23, pp. 823-830 Number 9, Taylor&Francis. USA.

Agarwal, A.K. and Rajamanoharan, K., 2009, Experimental Investigations Of Performance And Emissions Of Karanja Oil And Its Blends In A Single Cylinder Agricultural Dizel Engine, Applied Energy, 86, 106-112

Aydın, H. (2016). Scrutinizing the combustion, performance and emissions of safflower biodiesel–kerosene fueled diesel engine used as power source for a generator, Energy Conversion and Management, Volume 117, Pages 400-409

Babaoğlu,M. ve Nazlıcan, A.N., 2007, Safflower, Soybean Breeding, Ministry of Agriculture and Rural Affairs Publication Department, Ankara, 35-36

BP, 2015. "Primary Energy." Statistical Review of World Energy June 2015, no. June: 5. http://www.bp.com/content/dam/bp/pdf/Energy-economics/statistical-review-2015/bp-statistical-review-of-world-energy-2015-primary-energy-section.pdf.

BP, 2016, "BP Energy Outlook 2016 Edition. Outlook to 2035."

Eryılmaz, T., Yesilyurt, M.K. (2016). Influence of blending ratio on the physicochemical properties of safflower oil methyl ester-safflower oil, safflower oil methyl ester-diesel and safflower oil-diesel, Renewable Energy, Volume 95, Pages 233-247

IEA, 2010. "World Energy Outlook." doi:10.1787/weo-2005-en.

IEA, 2013. "Renewable Energy." World Energy Outlook 2013, 197–232.http://www.worldenergyoutlook.org/media/weowebsite/2013/WEO2013_Ch06_Renewables.pdf\nhttp://www.worldenergyoutlook.org/publications/weo-2013/.

IEA, 2015a. "Key World Energy Statistics 2015," 81. doi:10.1787/9789264039537-en.

IEA, 2015b. "World Energy Outlook 2015 Factsheet." Global Energy Trends to 2040:The Energy Sector and Climate Change in the Run-up to COP21, 1–4. doi:10.1787/20725302.

IEA, 2015c. "World Energy Outlook 2015." World Energy Outlook 2015: Presentation to the Press, London, 10 November 2015, no. November. http://www.worldenergyoutlook.org/media/weowebsite/2015/151110_WEO2015_presentation.pdf.

İlkılıç, C., Aydın, S., Behcet, R., AydIn, H. (2011). Biodiesel Fuel Processing Technology, Volume 92, Issue 3, March 2011, Pages 356-362

Mihaela, P., Josef, R., Monica, N., Rudolf, Z. (2013). Perspectives of safflower oil as biodiesel source for South Eastern Europe (comparative study: Safflower, soybean and rapeseed), Fuel, Volume 111, Pages 114-119

Muciño, G.G. Romero, R. Ramírez, Martínez, A.S.L., Baeza-Jiménez, R., Natividad, R. (2014). Biodiesel production from used cooking oil and sea sand as heterogeneous catalyst, Fuel, Volume 138, Pages 143-148

Öğüt, H., Eryılmaz, T. ve Oğuz, H. 2007, Some of Safflower (Carthamus tinctorius L.) A comparative study of the type produced Biodiesel Fuel Properties, 1st National Oil Crops and Biodiesel Symposium, pp.13-19.

Öğüt, H., Oğuz H., Bacak S., Mengeş H. O., Köse A., Eryılmaz T., 2011, Balcı Çeşit Aspirin Biyodizel Özelliklerinin İncelenmesi, Enerji tarımı ve Biyoyakıtlar Çalıştayı, Konya

Özçelik, A.E. (2011). Single Cylinder of safflower biodiesel and diesel fuel with a mixture Determining the Effects of Lubricating Oil in Diesel Engines, PhD Thesis, Selcuk University, Institute of Science, Konya,

Özsezen, A.N., ve Çanakçı, M., 2008, Investigation of Waste Frying Oil Methyl Ester Obtained From The Front Room Of Combustion Use A Diesel Engine Performance and Emissions Impact, Gazi Üniversitesi Mühendislik ve Mimarlık Fakültesi Dergisi, 23 /2/ 395-404

Öztürk, Ö., Uyanöz, R., Ada, R. ve Karaca, Ü. (2010). Different Forms of Phosphorus Fertilizer in Aspen and Administration Application (Carthamus tinctorius L.) Effect of Oil Yield, Ege University. Journal of Agriculture. Special Issue (5th National Congress of Plant Nutrition and Fertilizer), pp.197-202,

Pieprzyk, B., Kortlüke, N. and Hilje, P.R., 2009, The İmpact Of Fossil Fuels, Greenhouse Gas Emissions, Environmental Consequences And Socio-Economic Effects, *ERA* – Energy Research Architecture, Final Report, 225-232

Pourzolfaghar, H., Abnisa, F., Wan Daud, W.M.A., Aroua, M.K. (2016). A review of the enzymatic hydroesterification process for biodiesel production, Renewable and Sustainable Energy Reviews, Volume 61, Pages 245-257

Sajjadi, B., Raman, A.A.A., Arandiyan, H. (2016). A comprehensive review on properties of edible and non-edible vegetable oil-based biodiesel: Composition, specifications and prediction models, Renewable and Sustainable Energy Reviews, Volume 63, Pages 62-92

Saluja, R.K., Kumar, V., Sham, R. (2016). Stability of biodiesel – A review, Renewable and Sustainable Energy Reviews, Volume 62, Pages 866-881

Shahrokhnia, M. H., Sepaskhah, A.R. (2016). Effects of irrigation strategies, planting methods and nitrogen fertilization on yield, water and nitrogen efficiencies of safflower, Agricultural Water Management, Volume 172, Pages 18-30

Thangaraja, J., Anand, K., Mehta, P.S. (2016). Biodiesel NO_x penalty and control measures - a review, Renewable and Sustainable Energy Reviews, Volume 61, Pages 1-24

Thomas, T.P., David M., Dick B., Auld, L. (2012). Viscosity reduction of castor oil esters by the addition of diesel, safflower oil esters and additives, Industrial Crops and Products, Volume 36, Issue 1, Pages 267-270

Weiss, E.A., 2000, Safflower, In: Oilseed Crops, Blackwell Sci. Ltd., Victoria Australia, pp.93-97