Effect Of Terebinth Oil Biodiesel On Exhaust Emissions in a Ci Engine

Cumali Ilkilic[1],   Erdal Cilgin[2],*

[1]*Technology Faculty, Firat University, Elazığ, Turkey*
[2]*Centre of Vocational Training, Diyarbakır, Turkey*

Özet

Bu çalışmada saf dizel yakıtı ve dizel-biyodizel karışımlarının yanma ve egzoz emisyonları incelenmiştir. Araştırmada, menengiç yağından ilk olarak transesterifikasyon yöntemi ile biyodizel elde edilmiştir. Transesterifikasyon işleminden sonra ham menengiç yağı biyodizel viskozitesi, önemli ölçüde azalmış ve ısıl değeri atrmıştır. Menengiç yağı biyodizel üretiminden sonra, hacimsel olarak dizel yakıtı ile karıştırılmış ve B25 olarak adlandırılmıştır. Bu araştırmanın ikinci aşamasında,deneyler dört zamanlı enjeksiyonlu (CI) dizel motoru içinde saf dizel yakıtı ve dizel biyodizel karışımı (B25 yakıt) ile yapılmıştır. Konvansiyonel dizel yakıtı ile karşılaştırıldığında, dizel-biyodizel karışımları düşük karbon monoksit (CO), hidrokarbon (HC) ve karbon dioksitler (CO_2) vermiş ancak azot oksit (NOx) emisyonlarının yüksek olduğu görülmüştür.

Anahtar Kelimeler: Alternatif yakıtlar, Menengiç yağı, Biyodizel, dizel yakıt, Emisyon

Abstract

In this study combustion and exhaust emissions with neat diesel fuel and diesel–biodiesel blends have been investigated. In the investigation, firstly biodiesel from menengic oil has been obtained by transesterification method. The viscosity of raw menengic oil biodiesel, obtained after transesterification, was reduced considerably and heating value was improved. After producing biodiesel from menengic oil, it volumetrically mixed with diesel fuel as a named B25 fuel. In the second phase of this

investigation, experiment has been conducted with neat diesel fuel and biodiesel blend (B25 fuel) in a four stroke compression injection (CI) diesel engine. Compared with conventional diesel fuel, diesel–biodiesel blends showed lower carbon monoxide (CO), hydrocarbon (HC) and carbon dioxides (CO_2) but higher oxides of nitrogen (NO_x) emissions.

Key Words: Alternative fuels, Menengic oil, Biodiesel, Diesel fuel, Emission

1. INTRODUCTION

The prevalence of internal combustion engines and subsequent developments in engine technology have led to wide spread consumption of the petroleum fuels. Due to the shortage of petroleum products and its increasing cost, many efforts are put on the stage to develop alternative fuels, especially for full or partial replacement of diesel oil. The high cost of petroleum and petroleum crises have brought much pressure on many countries to re-evaluate their national energy strategies. Thus energy conservation and alternative fuels research are given high priority in energy planning in some countries. Many studies have been performed in developed countries and elsewhere involving vegetable oils as a primary source of energy. Particularly, during the early 1980's, studies on the possibility of using unmodified vegetable oils as a diesel fuel were conducted.

Since the petroleum crises in 1970's and 1980's, rapidly increasing petroleum prices and uncertainties concerning petroleum availability, a growing concern of the environment, and the gases affecting global warming have attracted more interests in the use of vegetable oils as a substitute of diesel fuel. The acceptability of vegetable oils as diesel fuel has been evaluated for the first time in the 70th years because of the well known energy crises. Thus energy conservation and alternative fuel researches are given high priority in energy planning in some countries. Several studies conducted worldwide have shown that vegetable oil, without any modification on diesel engine, can give performances comparable with those of diesel fuels. The most important advantage of vegetable oils is that they are renewable energy sources compared to the limited resources of petroleum. Many of these studies are on vegetable oils to be used in

diesel engines [1-8]. It has been found that the vegetable oils are promising fuels because their properties are similar to diesel and can be produced easily from the crops [9-11].

Vegetable oils are non-toxic renewable sources of energy, which do not contribute to the global CO_2 buildup. Vegetable fuels can be used as an emergency energy source in the event of any petroleum shortage. Extensive studies on alternative fuels for diesel engines have been carried out since the fossil based fuels are limited. Common vegetable oils are sunflower, cottonseed, olive, soybean, corn, nut, linseed, menengic and sesame oils. The most produced ones in Turkey are sunflower, cottonseed, corn, soybean, olive and nut oils.

Menengic and other vegetable seeds release oil on compression processes. During the processes of compression of these seeds and final storage, many fatty acids are formed [12-15]. These are palmitic, stearic, oleic, linoleic, arachidic and behenic acids. Menengic oil also contains some fatty acids like other vegetable oils. The melting point of fatty acids rises with the length of the structural chain of acid. Some vegetable oil contains high concentrations of less common fatty acids. These oils are almost entirely consumed in foods. The excess of these could be used as diesel fuel besides consuming in foods.

Vegetable oil canbe used in internal combustion engine as fuel. It has been shown that pure vegetable oils have harmful effects on engine parts and cause a starting up problem [16-23]. The problems due to the viscosity and density of the vegetable oils having different physical and chemical properties from the diesel fuel should be eliminated by making them less viscous. High viscosity of the vegetable oils and its tendency to polymerise within the engine cylinder are major chemical and physical problems encountered. With this aim, it is necessary to obtain either esters or emulsions of vegetable oils [24-27]. Vegetable oils can be used as material to produce methyl or ethyl ester. There are several methods for producing of ester; and the best method is known as transesterification [28-38]. Even a blend of 20% biodiesel and 80% diesel fuel will significantly reduce carcinogenic emissions by 27% and gases that may contribute to global warming up [39,40,41]. In addition to this, Biodizel raw materials(rape,canola, sunflower,soybean,safflower) are chosen from agricultural products. In time, having been used an excessive amount of agricultural land is predicted to cause famine, price

increase of food products, erosion, loss of biodiversity and by affecting global food resources the long-term sustainability of agricultural production [42]. Due to excessive use of fertilizers and pesticides, pollution of surface and ground water is estimated to be lead. In this direction, a bıttım plant creating less pressure on agricultural areas and water resources is a plant being worked on [43].

2. MATERIAL AND METHOD

2.1. *Menengic plant*

Menengic (Pistacia terebinthus L.), known commonly as terebinth and turpentine tree, is a species of Pistacia, native to the southern and western Turkey. In the eastern shores of the Mediterranean Sea a similar species fills the same ecological niche as this species and is also known as terebinth. It is named as "bıttım" the area around of Siirt, Turkey.

Pistacia terebinthus is a broad, deciduous bushy tree that grows slowly to the height and breadth of a wide field. It is a small deciduous tree or large shrub growing to 10 m tall. The leaves are compound, 10-20 cm long, odd pinnate with five to eleven opposite glossy oval leaflets, the leaflets 2-6 cm long and 1-3 cm broad. The flowers are reddish-purple, appearing with the new leaves in early spring. Its fruit appear like small spherical nutlets and turn brown when mature. The fruit consists of small, globular drupes 5-7 mm long, red to black when ripe. Its fruit has been eaten as an appetizer in southern Turkey since ancient times. It is used for the treatment of sunstroke, stomachache, gastric ailments, rheumatism, and coughs, and as a stimulant and diuretic in Turkish alternative medicine. It is the source of market products such as dried whole fruit, gummy extract and a special soap, known as "menengic soap" or "bittim soap", which contains a different proportion of terebinth oil. All parts of the plant have a strong resinous smell. The plant is rich in tannin and resinous substances and has been known since ancient times for its aromatic and medicinal properties. In different regions of the world, the terebinthus tree is used for various purposes. Young shoots and fruits are used for nutrition. Because the plant is in current use in the form of fruit, fruit extracts (gummy extract) as well as in the production of special soaps, analysis of the

inorganic constituents is useful. Physical and chemical properties of menengic oil used in this study in comparison with other some vegetable oils are given in Table 1.

Table 1. Physical and chemical properties of terebinth oil in comparison with other some vegetable oils

	Terebinth oil	Sunflower oil	Corn oil	Soybean oil
Calorific value (kJ/kg)	39100	39500	37850	39620
Density @ 26°C (Kg/lt)	0.921	0.918	0.919	0.914
Viscosity (mm^2/s) at 26°C	44.85	58	39	65
Flash point (°C)	228	220	277	230
Cetan number	46	37	38	38

2.2. *Biodiesel production from menengic oil*

Biodiesel is the monoalkyl ester of long chain fatty acids derived from renewable feedstocks, such as vegetable oil or animal fats, for use in compression ignition engines. Biodiesel is commonly composed of fatty acid methyl esters (biodiesel) that can be prepared from triglycerides in vegetable oils by transesterification with methanol. Biodiesel consists of mono-alkyl esters formed by a catalyzed reaction of the triglycerides in the oil or fat with a simple monohydric alcohol. There were no significant differences between the chemical and physical specifications of biodiesel and diesel fuels. Therefore biodiesel can be used in all diesel engines as fuel. Transesterification of triglycerides produce fatty acid alkyl esters and glycerol. The glycerol layer settles down at the bottom of the reaction vessel and can be used for many purposes. The overall transesterification reaction is given in reversible equations as shown in Fig. 1.
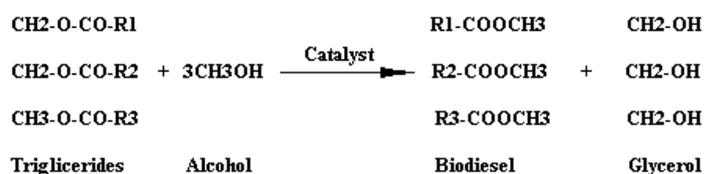
Fig. 1. General equation for transesterification.

Methanol containing 1% sulphuric acid (H_2SO_4) can methylise the fatty acids very rapidly. Methanol and oil mixture in a certain proportion can be transformed to biodiesel by holding at 50°C for 12 hours. In particular biodiesel derive by the reaction

between triglicerides and methanol. We prepared our study to determine whether the biodiesel of these common fatty acids as diesel fuels. Biodiesel of menengic oil were prepared with a four molar excess of the alcohol containing 2% H_2SO_4 as catalyst. It had been waited for 12 hours in the bath oil with $50^{o}C$. In this study also menengic biodiesel (MB) was obtained in following way. The purpose of this paper is to review the use of MB and diesel fuel blend.

The menengic oil was filled into a flask. An amount of methyl alcohol equal to 50% of prepared oil was mixed with 1% H_2SO_4, volumetrically. Then the mixture of alcohol and H_2SO_4 was added to the flask containing menengic oil. The mixture was heated and then stired between 50 and $60°C$ until the oil was completely solved and liquefied in the alcohol. The mixture of oil-alcohol-catalyzer was heated at permanent temperature of $60°C$ until 12 hours. After 12 h, the reaction products were separated into two layers, the top one was biodiesel and the bottom one was glycerol. The biodiesel layer was separated from glycerol. Then n-hegzan (C_6H_{14}) was added into biodiesel for washing it. The biodiesel was then dried with sodium sulphate (Na_2SO_4). The obtained biodiesel was added to diesel fuel volumetrically by 50%. The fuel mixtures that obtained from the addition of 50% of biodiesel were named here as B50 fuel. The resulting biodiesel is quite similar to conventional diesel fuel in its main characteristics The chemical and physical properties of raw menengic oil, pure biodiesel (B100), B50 fuel and diesel fuel are presented in the Table 2.

Table 2. Physical and chemical properties of menengic oil (MO), menengic biodiesel blend (B50 fuel), menengic biodiesel (B100 fuel) and diesel fuel (DF)

	ASTM test no	MO	B50 fuel	B100 fuel	Diesel fuel
Viscosity(mm^2/s)	D445	44,85	3,89	4,12	3,66
Heat value (J/kg)	D2015	39100	41100	40100	43350
Density (15 C) (g/ml)	D1298	0,92	0,86	0,88	0,83
Flash point (°C)	D93	228	69	75	60
Cetane index	D613	46	52	55	57

3. EXPERIMENTAL EQUIPMENTS AND TEST PROCEDURE

Prepared biodiesel from menengic oil in laboratory conditions was mixed volumetrically 50% with diesel fuel (B50 fuel) and tested in a following detailed engine

in the Table 3. Experiments were carried out in Engine Test Laboratory of Automotive Department of Technical Education Faculty at University of Batman, Turkey. The schematic diagram of the experimental setup is shown in Fig. 2. Tests were conducted on a single cylinder, four strokes, air cooled diesel engine.

Table 3. Technical specifications of the test engine

Type and modal	Rainbow-186 Diesel
Injection system	Direct injection
Cylinder number	1
Stroke volume	406 cc
Compression ratio	18/1
Maximum power	10 HP
Maximum engine speed	3600 rpm ±20
Cooling system	Air cooling
Injection pressure	19.6±0.49 Mpa (200±5 kgf/cm2)
Mean effective pressure	561.6 kpa
Medium piston speed	7.0 m/s (at 3000 rpm)
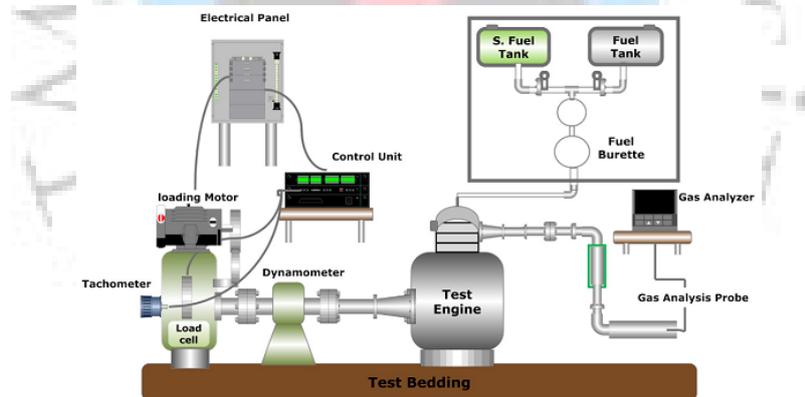
Fig. 2. A schematic diagram of the engine setup.

Engine tests were conducted on a BT-140 model hydraulic dynamometer. Technical specifications of the hydraulic dynamometer control unit and the dynamometer are given in Tables 4 and 5. Exhaust gas emissions were measured with MDO 2-LON type gas analyzer and specification of this device is given in Table 6. The CAPELEC CAP 3200 brand exhaust gas analyzer was used to measure emissions of the test fuels. Percentages of carbon dioxide (CO_2) (%), carbon monoxide (CO) (%), nitrogen oxide (NOx) (ppm), hydrocarbon (HC)(ppm) and oxygen (O_2) (%) were

determined by gas analyzer apparatus. The technical specifications of the device have been presented in the Table 6.

An infrared temperature measurement device was used to specify exhaust gas temperature. The technical specifications of the temperature measurement device are presented in the Table 7.

Table 4. Technical specifications of the dynamometer control unit.

Model	PC101BMS
Accuracy	% 0.2
Precision	±1 digit
Response time	600 μs
Weight measurement	Linear (load-cell)
Speed measurement	Sensor
Screen type	3×6 unit, 7-region LED 2×16 character LCD
Power	16W
Operation temperature	0–50°C
Operation voltage	220±%5 VAC
Output	Printer

Table 5. Technical specifications of the dynamometer

Brake motor	BT-140
Maximum brake power	50 HP
Maximum speed	7500 rpm
Maximum torque	250 Nm
Capacity of load cell	1000 N
Water consumption for maximum power	V max.. 0.75 m³/h
Brake water pressure	1–2 kg/cm²
Brake control type	Slippery propeller
Electricity requirement	220/380 V. 50 Hz

Table 6. Technical properties of the gas analyzing device

	Measuring range	Precision
HC	0–20,000 ppm	1 ppm
CO_2	%0–21	%0.1
CO	%0–10.5	%0.001
O_2	%0–21.7	%0.01
NOx	0–10,000 ppm	1 ppm

Table 7. The technical specifications of the temperature measurement device

Type	Raytek Raynger ST4
Temperature measurement range	(−32 to 545°C) (−25 to 950°F)
Laser type	Single point
Diffusion rate	% 95
Precision	%±1
Response time	500 μsn

4. RESULTS AND DISCUSSIONS

4.1. *Exhaust emissions*

Fuels for internal combustion engines are often mixtures of hydrocarbons and petroleum is consist of hydrocarbon as well. When petroleum based fuels burn in an engine the main substances present in the emission gasses in exhaust are incomplete oxides of hydrocarbon containing CO, NOx, HC, soot containing SO_2 emissions and particulates. CO emission is the most toxic substance found in exhaust gasses and is colorless, tasteless and odorless. CO is a poisonous gas that, when inhaled, replaces the oxygen in the blood stream so that the body's metabolism cannot function properly. Although it has no smell, small amounts of CO concentration, slow down physical and mental activities and produce headaches, while large amounts can kill. HC and CO emissions are main products of incomplete combustion.

4.1.1. *Carbon dioxide (CO_2) emissions*

The combustion of fossil fuels produces carbon dioxide (CO_2), which is getting accumulated in the atmosphere and is leading to many environmental pollution problems. The combustion of biofuels also produces carbon dioxide, but crops are readily absorbing CO_2 and, hence, CO_2 levels are kept in balance. It is very important to observe that, in a global balance, these fuels can limit strongly the rise of CO_2 in the atmosphere because of their vegetal origin.
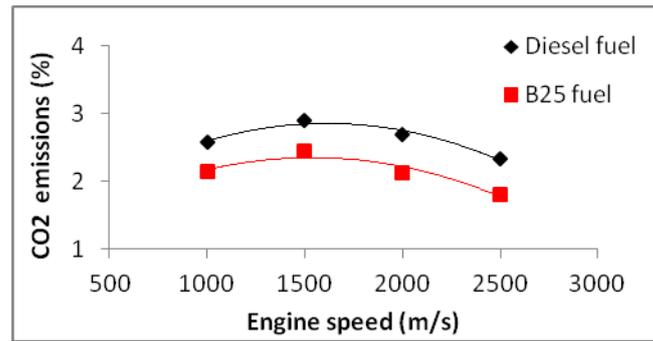
Fig. 3. The variation of the carbondioxide (CO_2) at the various engine speed.

Carbon dioxide emission is an emission product related to the entire combustion of the fuel. The increase in CO_2 production with diesel fuel must be due to efficient combustion. The high viscosity of B50 fuel must have acted positively to the engine compression and combustion processes. High post-combustion temperature and existence of enough oxygen for an exact burning increase the amount of CO_2. The results of percentage CO_2 emissions of the two fuels are superimposed as shown in Fig. 3. These plots did not show any marked difference between the fuels at low engine speed. However, at all of the engine speeds, the diesel fuel showed a marginal increase in CO_2 emissions over B50 fuel. The CO_2 emission decreased with the increase in engine speed for these two fuels. It is seen from CO_2 amount-engine speed graphics that CO_2 amount is higher around 2500 m/s engine speed for both fuels. It is also understood that the best burning happened near this speed. The CO_2 emission is 3.3% for diesel fuel and 2.9% for B50 fuel at 2000 m/s. One noticeable event is that the emissions of CO_2 appeared to be influenced by fuel viscosity. The emissions of CO_2 were noted to increase as the viscosity increases. It is well known that a decrease in cone angle results in reduction of the amount of air entrainment in the spray. The cone angle in which air entrainment depends, decreases with increased fuel viscosity. This is expected to affect combustion characteristics of the fuel.

4.1.2. *Carbon monoxide (CO) emissions*

Carbon monoxide is exerted as a result of inadequate burning and partial oxidation of carbon atoms in fuel. This emission changes depending on the air/fuel ratio in cylinders. When this ratio is small, the amount of CO increases. As the general trend

the CO emissions fairly reduced when substituting diesel fuel with biodiesel and this can be seen in Fig. 4. The lowest CO emissions were found for B50 fuel in average. The decrease in CO emissions for B20 was similar to that for B50. Several reasons can be given for such decrease. Firstly, it may be due to the additional oxygen content in the fuel, which enhances a complete combustion of the fuel, thus reducing CO emissions. When the air is insufficient, CO transforms to CO_2 after a certain amount of air. As can be seen from CO_2-engine speed relationship, CO emission tends to decrease with the increase in engine speed. Secondly, it can be attributed to the higher cetane number of biodiesel fuel that puts the fuel-rich mixture zone away and improves combustion thus reducing CO emissions. Finally, the advanced injection time of biodiesel use due to molecular structure of biodiesel may also explain the reduction in CO emissions. Thirdly, since turbulence occurs in the combustion chamber at higher speeds, burning improves and due to the increase of the temperature of the mixture, Co emission decreases. When the engine speed decreases and the loading is increased, the quality of burning get worse and CO emission rises.When OH radical which transforms CO to CO_2 decreases below $1500^{o}K$, burning deteriorates and consequently, amount of CO increases due to the lower temperature [31].
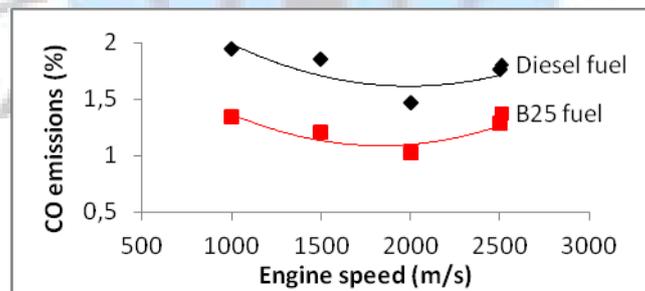
Fig. 4. The variation of the carbonmonoxide at the various engine speed.

Fig. 4 shows the carbon monoxide emissions for two different fuels under different engine speeds. One can observe from Fig. 5, that the CO emitted by B50 fuel is lower than the ones for the corresponding diesel fuel case. This can be explained by the enrichment of oxygen owing to the biodiesel addition, in which an increase in the proportion of oxygen will promote the further oxidation of CO during the engine exhaust process. As shown in Fig. 4, CO emission was lower with B50 fuel compared with diesel fuel at all engine speeds. Similar results were also reported by other

researchers [39-41]. As can be seen from CO and engine speed relation, CO emission tends to decrease with the increase in engine speed. When the OH radical, which transforms CO to CO_2, decreases below 1500^oK, burning deteriorates and, consequently, the amount of CO increases due to the lower temperature as shown in the following equations:

$CH_3 + O_2 \rightarrow CHO + H_2O$

$CH_2 + O_2 \rightarrow CO + H_2O$

$CHO + OH \rightarrow CO + H_2O$
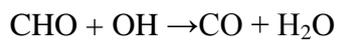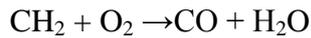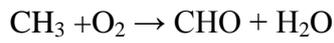
This is typical with all internal combustion engines since the air/fuel ratio decreases with increased load. Since turbulence occurs in the combustion chamber at higher speeds, burning improves and, due to the increase of the temperature of the mixture, CO emission decreases. At the middle speeds of engine test fuels were showed lower CO emissions. It can be attributed to the enriched O_2 in the combustion chamber accompanied by sufficient turbulence created by increased mean piston speed.

When the engine speed decreases and the loading increases the quality of burning gets worse and CO emission rises. The CO emission it defined as CO emission (%) divided by the corresponding fuel consumption rate. It was found that the CO emission decreased with the increase in engine speed. As for higher engine speed there should not be enough time for complete combustion resulted more CO emissions again. One can also observe from this Fig. that the BE20 blend fuel tends to produce lower exhaust CO values than the corresponding ones for the B50 case.

4.1.3. *Hydrocarbon (HC) emissions*

The exhaust gasses contain many different HC compounds. The total unburned hydrocarbons were measured as "ppm" with the gas analyzer. The variations of HC emission with engine speed for diesel fuel and B50 fuel is presented in the Fig. 5.
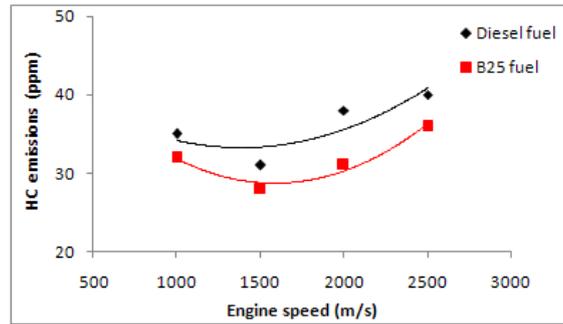
Fig. 5. The variation of the hydrocarbon emissions at the various engine speed.

The Fig. shows the comparison of the results of B50 fuel with the baseline diesel fuel. B50 fuel operation produced the highest HC emissions compared to the results of diesel fuel. The HC emission which is one of the organic compounds is formed in the result of incomplete combustion. HC emissions fairly increase in the case of richer fuel–air ratios above the stoichiometric ratio. Besides, in the excessively leaned fuel–air ratio conditions, due to incomplete combustion that resulted from the lack of oxygen, HC emissions rapidly increase again. Normally, as the fuel viscosity is decreased, the penetration rate decreases and the spray cone angle increases. With B50 fuel, the penetration rates increased as the viscosity was reduced by increasing the temperature of the biodiesel. The HC emissions were noted to increase with decreased fuel viscosity. In many cases, the HC emissions for B50 fuel have been reported higher than that of diesel fuel. It can be attributed to the oxygen content in the biodiesel molecule, which leads to a more complete and cleaner combustion. The higher cetane number of diesel fuel shortens the combustion delay and thus reduces HC emissions. However, at high and low engine speed, and combustion temperature, B50 fuel showed an increase HC emissions over the diesel fuel.

4.1.4. Nitrogen oxides (NOx) emissions

Nitrogen oxide is the generalized term for NO and NO_2 given with the formulae of NOx. Nitrogen oxide is formed as a result of the oxidation of nitrogen in the air during burning of the air-fuel mixture in the combustion chamber. Its formation is dependent on the duration of the flame temperature in the combustion chamber above 1800^oK [32]. The test results showed an increase in NOx emission when using B50 fuel.

The obtained increase in NO_x emissions was in proportion to the biodiesel concentration in the blend as can be seen in Fig. 6.
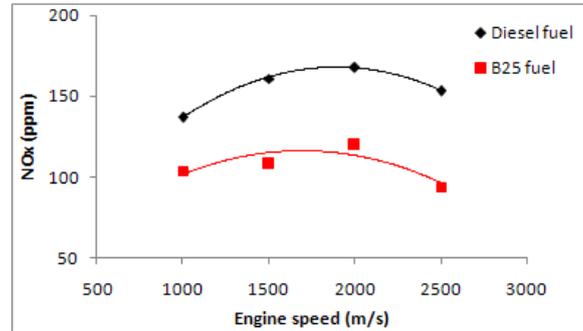
Fig. 6. The variation of the nitrogen oxide at the various engine speed.

When the burning temperature is above 1800^oK, NOx formation considerably accelerates. The lowest NOx emissions were obtained with using diesel fuel and the highest NOx emissions were obtained with B50 fuel. The main reason for NOx increase is the oxygen content of biodiesel which improves combustion thus increases the temperature and resulting NOx production reaction which occurs after 1800°K. In the formation of nitrogen oxides, the prodominant factors are the air/fuel ratio and the environment temperature. In case of adequate burning the temperature rises and consequently more free oxygen atoms combine nitrogen increasing the formation rate of nitrogen oxide. In poor mixtures, first O_2 is decomposed to 2O. Then it is accepted that NO forms with free radicals. Another argument is the increased cetane numbers of biodiesel which leads to advanced combustion by shortening ignition delay which promotes NOx formation reactions. Since the activation energies of these reactions are high, both reactions in lower temperatures are very slow. Since cetane number of biodiesel increases in proportion to the concentration of biodiesel in the blend, B50 blend resulted in the highest NOx emission. As can be seen from Fig. 5, at first the increase in NOx emission for both fuels with the increase in engine speed and then decrease after a certain speed support this. From both graphics of emissions, it is seen that the best burning is in the maximum torque range. This also means that the maximum temperature is reached in this range and NOx emissions are higher. One more parameter that effects on NOx is iodine number. Biodiesel has higher number of iodine which results in higher NOx emission.

4.1.5. *Oxygen (O₂) emissions*

The amount of power an engine can produce is limited by how much fuel it can burn, and the amount of fuel it can burn is limited by the amount of air in the engine cylinder. The air is composed of oxygen and nytrogen. The amount of oxygen in the engine cylinder is limited by the amount of air in the cylinder. Increasing the oxygen flow to the diesel engines reduces particulate emissions and increases engine power output. The oxygen (O_2) emission for B50 fuel and diesel fuel as the engine test fuels under varied engine speeds are shown in Fig. 7.
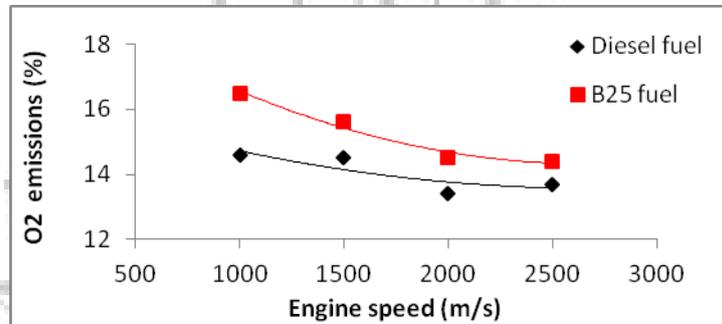
Fig. 7. The variation of the oxygen emissions at the various engine speed.

The variations of oxygen (O_2) for running the diesel engine by B50 fuel was compared with that by diesel fuel in Fig. 7. The amount of oxygen decreases from 14.6% to about 12.7% when the engine speed is increased from 1000 m/s to 2500 m/s for diesel fuel. In the case of B50 fuel, it is seen that O_2 emission is higher at all engine speeds. This means that the B50 fuel contains more oxygen than diesel fuel.

4.1.6. *Exhaust gas temperature*

The variation of the exhaust gas temperatures of the test fuels were evaluated on a graph.The exhaust temperatures of the engine when using diesel fuel and B50 fuel were presented in the Fig. 8.
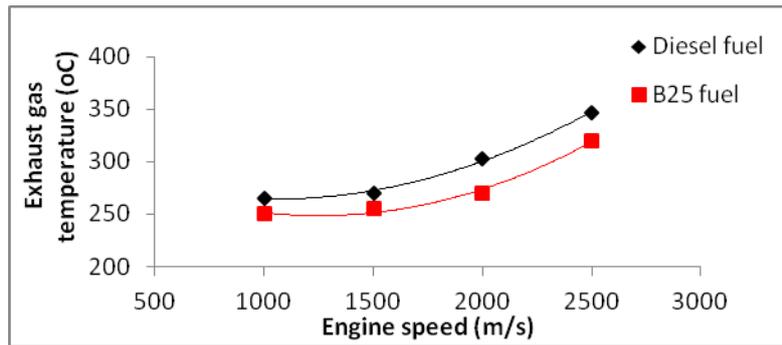
Fig. 8. The variation of the exhaust gas temperature at the various engine speed.

Exhaust gas temperatures of the fuels changes change with the factors such as viscosity, heat capacity and flame velocity during burning. Low viscosity causes poor atomization which leads to the longer ignition times and continuation of burning in the expansion stroke. Consequently post burning pressure and temperature become lower. The exhaust temperature increased almost linearly with the increase in engine speed for two test fuels. It can be seen clearly in the Fig. 6 that the higher temperature values were obtained for biodiesel blend fuels and the increase was observed the highest for B50 fuel. At higher engine speeds, spreading of the burning in the exhaust system causes the temperature of the exhaust gases to rise. If the heat capacity of the fuel is high, the energy exerted during combustion gets higher and subsequently the energy of the exhaust gas is higher. It can be attributed to the more complete combustion for biodiesel use thanks to the oxygen that was inherently contained in the biodiesel.

5. CONCLUSIONS

In this study, an alternative biodiesel fuel was obtained from menengic seed oil by the transesterification method. Some of important physical and chemical fuel properties of the oil, pure biodiesel and biodiesel blend fuels as well as diesel fuel were found. By the production process, the viscosity and density of the oil decreased while the calorific value slightly increased. While the density and viscosity of MO fuel decreased from 0.92 kg/l to 0.86 kg/l and from 44.85 mm^2/s to 3.89 mm^2/s respectively at 26°C, the heat capacity increased from 39100 kJ/kg up to 41100 kJ/kg. B50 fuel

produced has more similar properties to diesel fuel compared with MO. Especially viscosity considerably decreased as a result of esterification. It was found that the fuel properties of the biodiesel blend, which was named as B50 fuel, were fairly similar to that of diesel fuel.

Carbon dioxide (CO_2) emissions measured in the experiments with diesel fuel are higher than of B50 fuel for all the engine speeds. CO2 decreased by 31% when B50 fuel was compared to diesel fuel. Maximum CO_2 emission was measured at the engine speed (2500 m/s) for the maximum engine power for both fuels. CO was reduced by 47% when B50 fuel was compared to diesel fuel. The same results are not valid for NOx emission. Nitrogen oxide emission for B50 fuel was increased when it was compared to diesel fuel. NOx and CO_2 emissions are maximum in the range of maximum burning efficiency. Considered exhaust emissions it can be concluded that B50 fuel is superior to diesel fuel.

All these arguments showed that due to the improved combustion with the use of biodiesel, it made the performance of the engine remain higher than expected. The positive effects of B50 fuel were found in the reducing of CO, HC and CO_2 emissions. The decrease in these emissions was proportional to B50 fuel contained in the blend. As a result, B50 fuel is less toxic, more biodegradable, has no harmful effects on bio life, and it is environmentally friendly. It is one of the most important fuels for reducing greenhouse gases and, thus, it is suited to global warming to maintain and follow the Kyoto Protocol.

REFERENCES

[1] Labeckas G, Slavinskas S. Performance and exhaust emissions of direct-injection diesel engine operating on rapeseed oil and its blends with diesel fuel. Transport 2005;20:186-194.

[2] Lapuerta M, Armas O, Ballesteros R, Fernández J. Diesel emissions from biofuels derived from Spanish potential vegetable oils. Fuel 2005;84:773-780.

[3] Huzayyin AS, Bawady AH, Rady MA, Dawood A. Experimental evaluation of diesel engine performance and emission using blends of jojoba oil and diesel fuel. Energy Convers Manage 2004;45:2093-2112.

[4] Hebbal OD. Vijayakumar Reddy K, Rajagopal K. Performance characteristics of a diesel engine with deccan hemp oil. Fuel 2006;85:2187-2194.

[5] Ryu K, Oh Y. Combustion characteristics of an agricultural diesel engine using biodiesel fuel, KSME Int J 2004;18:709-717.

[6] Rakopoulos CD. Olive oil as a fuel supplement in DI and IDI diesel engines. Energy 1992;17:787-790.

[7] Geyer, S.M., Jacobus, M.J., Lestz, S.S. 1984. Comparison of diesel engine performance and emissions from neat and transesterified vegetable oils. Transact Am Soc Agric Eng 1984;27:375-381.

[8] Yoshimoto Y, Tamaki H. 2002. Performance and emission characteristics of diesel engines fueled by rapeseed oil-gas oil blends. Transact Japan Soc Mechan Eng Part A 2002;68:3191-3198.

[9] Jung H, Kittelson DB, Zachariah MR. The characteristics of diesel particles emissions and kinetics of oxidation using biodiesel as fuel, International Symposium on Combustion, Abstracts of Works-in-Progress Posters, p. 176, 2004.

[10] Zou L, Atkinson S. Characterising vehicle emissions from the burning of biodiesel made from vegetable oil. Environ Technol 2003;24:1253-1260.

[11] Nagaraj AM, Prabhu Kumar KG. Emission and performance characteristics of a single cylinder compression ignition engine operating on esterified rice bran vegetable oil and diesel fuel. ASME, ICE Division 2002;39:389-394.

[12] Gunstone F. Cottonseed oil - significant oil in seven countries, INFORM - International News on Fats. Oils and Related Materials 2003;14:72-73.

[13] Bikou E, Louloudi A, Papayannakos N. The effect of water on the transesterification kinetics of cotton seed oil with ethanol. Chem Eng Technol 1999;22:70-75.

[14] Warner, K., Orr, P., Glynn, M. Effect of fatty acid composition of oils on flavor and stability of fried foods. J Am Oil Chem Soc 1997;74:347-356.

[15] Yucesu HS, İlkilic C. Effect of cotton seed oil methyl ester on the performance and exhaust emission of a diesel engine Energy Sources Part A 2006;28:389-398.

[16] Engler CR, Johnson LA, Lepori WA, Yarbrough CM. Effects of processing and chemical characteristics of Plant oils on performance of an indırect-injection diesel engine. J Am Oil Chem Soc 1983;60:1592-1596

[17] Schlick ML, Hanna MA, Schinstock JL. Soybean and sunflower oil performance in a diesel engine. Transact Am Soc Agric Eng 1988;31:1345-1349.

[18] Ramadhas AS. Use of vegetable oils as I.C. engine fuels—a review. Renew Energy 2004;29:727–742.

[19] Muñoz M, Moreno F, Morea J. Emissions of an automobile diesel engine fueled with sunflower methyl ester. Transact Am Soc Agric Eng 2004;47:5-11.

[20] Bari S, Lim TH, Yu CW. Effects of preheating of crude palm oil (CPO) on injection system, performance and emission of a diesel engine. Renew Energy 2002;27:339-351.

[21] Goodrum JW, Geller DP. Influence of fatty acid methyl esters from hydroxylated vegetable oils on diesel fuel lubricity, Biores Techenol 2005;96:851-855.

[22] Dorado MP, Arnal JM, Gómez J, Gil A, López FJ. The effect of a waste vegetable oil blend with diesel fuel on engine performance. Tansact Am Soc Agric Eng 20023;45:519-523.

[23] Krishna MVSM, Prasad CMV, Murthy PVK, Reddy TR. Studies on pollution levels from low heat rejection diesel engine with vegetable oil-pongamia oil. Indian J Environ Protect 2004;24:420-425.

[24] Bhattacharyya S, Reddy CS. Vegetable oils as fuels for internal combustion engines: A review. J Agric Eng Res 1994;57:157-166.

[25] Agarwal AK, Das LM. 2001. Biodiesel development and characterization for use as a fuel in compression ignition engines. J Eng Gas Turbines Power 2001;123:440-447.

[26] Barnwal BK, Sharma MP. Prospects of biodiesel production from vegetable oils in India. Renew Sustain Energy Rev 2005;9:363-378.

[27] Schwab AW, Bagby MO, Freedman B. Preparation and properties of diesel fuels from vegetable oils. Fuel 1987;66:1377-1378.

[28] Freedman B, Butterfield RO, Pryde EH. Transesterification kinetics of soybean oil. J Am Oil Chem Soc 1986;63:1375-1380.

[29] Mittelbach M, Enzelsberger H. Transesterification of heated rapeseed oil for extending diesel fuel. J Am Oil Chem Soc 1999;76:545-550.

[30] Schuchardt U, Sercheli R, Vargas RM. Transesterification of vegetable oils: A review. J Brazilian Chem Soc 1998;9:199-210.

[31] Ramadhas AS, Javaraj S, Muraleedharan C. Characterization and effect of using rubber seed oil as fuel in the compression ignition engines. Renew Energy 2005;30:795-803.

[32] Ilkilic, C, Yucesu HS. Investigation of the effect of sunflower oil methyl esther on the performance of a diesel engine. Energy Sources 2005;27:1225-1234.

[33] Megahed OA, Abdallah RI, Nabil D. Rapeseed Oil Esters as Diesel Engine Fuel. Energy Sources 2004;26:119-126.

[34] Dorado MP, Ballesteros E, López FJ. Mittelbach M. Optimization of alkali-catalyzed transesterification of Brassica Carinata oil for biodiesel production. Energy Fuel 2004;18:77-83.

[35] Encinar JM, González JF, Rodríguez JJ, Tejedor A. Biodiesel fuels from vegetable oils: Transesterification of Cynara cardunculus L. Oils with ethanol. Energy Fuel 2002;16:443-450.

[36] Noureddini H, Zhu D. Kinetics of transesterification of soybean oil. J Am Oil Chem Soc 1997;74:1457-1463.

[37] Ma F, Hanna MA. Biodiesel production: A review. Bioresour Technol 1999;70:1-15.

[38] Harrington KJ, D'Arcy-Evans C. Comparison of conventional and in situ methods of transesterification of seed oil from a series of sunflower cultivars. J Am Oil Chem Soc 1985;62:1009-1013.

[39] Petrowski J. 2002. Fuels & fueling: The age of biofuels, National Petroleum News, 94(6):32-34

[40] Ilkilic C. An analysis of exhaust emissions on a diesel engine operation by biodiesel. Energy Sources Part A 2011;33:298- 306.

[41] Ilkilic C, Behcet R. The reduction of exhaust emissions from a diesel engine by using biodiesel blend. Energy Sources Part A 2010;32:839–850.

[42] Ladanai, S. and Vinterback, J. (2009). "Global Potential of Sustainable Biomass for Energy". Uppsala: Swedish University of Agricultural Sciences. p32.

[43] Ayşe Neslihan SAY, Ülker Diler KERİŞ, Ünal ŞEN, Mirat D. GÜROL VIII. Ulusal Temiz Enerji Sempozyumu, UTES'10   1-5 Aralık 2010, Bursa