IJEASED

INTERNATIONAL JOURNAL OF EASTERN ANATOLIA SCIENCE ENGINEERING AND DESIGN

Uluslararası Doğu Anadolu Fen Mühendislik ve Tasarım Dergisi
ISSN: 2667-8764 , 2(1), 67-87, 2020
https://dergipark.org.tr/tr/pub/ijeased

Araştırma Makalesi / *Research Article*

As Lubricating Oil In A Two-Stroke Gasoline Engine Use Of Vegetable Oil

Salih ÖZER *

Mus Alparslan University, Faculty of Engineering-Architecture, Mus / Turkey

Yazar Kimliği / *Author ID (ORCID Number)*	Makale Süreci / *Article Process*	
**Sorumlu Yazar / *Corresponding author* : s.ozer@alparslan.edu.tr https://orcid.org/0000-0002-6968-8734 , S. Özer	**Geliş Tarihi / *Received Date*** : **Revizyon Tarihi / *Revision Date*** : **Kabul Tarihi / *Accepted Date*** : **Yayım Tarihi / *Published Date*** :	28.01.2020 29.03.2020 05.04.2020 15.07.2020

Alıntı / *Cite* : Özer, S. (2020). As Lubricating Oil In A Two-Stroke Gasoline Engine Use Of Vegetable Oil, International Journal of Eastern Anatolia Science Engineering and Design, 2(1), 67-87.

Abstract
Recently, legislation on the reduction of emissions from motor vehicles has led to intensive studies in this area. In these studies, it is observed that the research and use of alternative fuels, which are less polluting than petroleum-derived fuels, is emphasized. Especially in the field of lubrication, the alternatives to oils are being studied rapidly and the number of publications is increasing. In general, four-stroke engines are more focused on these studies while they are being carried out and studies about them in general are being carried out. What distinguishes this work from the others is that it covers two-stroke engines. Furthermore, the effect of the use of these oils on Wear has also been studied. In this study, motor oil and various vegetable oils were added to the gasoline by 5% and 10% volumetric (v/v), and the effects of these additives on fuel consumption and exhaust emissions were investigated experimentally. In addition, the amount of wear on the compression ring was determined in long-term 50-hour and 100-hour operation situations. As a result of the study, there was an increase in fuel consumption, is, HC, CO emissions and a decrease in NO_X and CO_2 emissions by using vegetable oil compared to petroleum-derived mineral oil. Vegetable oils have been shown to cause more wear on the compression ring than mineral oil.

Keywords: Two-Stroke Engine, Lubrication, Renewable Energy, Vegetable Oil, Exhaust Emissions.

İki Zamanlı Benzinli Bir Motorda Yağlama Yağı Olarak Bitkisel Yağ Kullanımı

Özet
Son zamanlarda motorlu taşıtlardan kaynaklanan emisyonlarının azaltılması üzerine yapılan yasal düzenlemeler, bu alanda yoğun çalışmaların yapılmasına neden olmuştur. Bu nedenle bu alandaki çalışmalar her geçen gün hız kazanmaktadır. Yapılan bu çalışmada benzinin içerisine hacimsel olarak (v/v) %5 ve %10 oranlarında motor yağı ve çeşitli bitkisel yağlar katılmış, bu katkıların yakıt tüketimi ve egzoz emisyonlarına etkileri deneysel olarak incelenmiştir. Ayrıca uzun süreli 50 saatlik ve 100 saatlik çalışma durumlarında 1. segmandaki aşınma miktarı tespit edilmiştir.

Çalışmada iki zamanlı benzinli bir motor kullanılmıştır. Yapılan çalışma sonucunda, petrol kaynaklı madeni yağa göre yenilenebilir yağ kullanılması ile birlikte yakıt tüketimi, is, HC, CO emisyonlarında artış ve NOx ile CO_2 emisyonlarında azalma meydana geldiği tespit edilmiştir. Segmanlardaki aşınmanın tespit edilmesi için yapılan 50 saatlik ve 100 saatlik çalışma sonrasında ise madeni yağ kullanımına göre her yakıt karışımında aşınma olduğu görülmüştür.

Anahtar Kelimeler: *İki Zamanlı Motor, Sürtünme, Yenilenebilir Enerji, Bitkisel Yağlar, Egzoz Emisyonu*.

1. Introduction

In parallel with the population growth, the use of motor vehicles powered by fossil-derived fuel is increasing every day. Climate changes and increasing costs caused by fossil-derived fuel use have necessitated the production of energy, particularly from waste or renewable sources (Simio et al. 2012). Spark-ignition and compression ignition engines as an alternative to petroleum based fuels used in various types of alcohol, hydrogen, acetylene, natural gas (CNG, LNG), various Fatty Esters (biodiesel) and on the availability of fuels are made in similar research (Kumar et al. 2005; Kumar et al. 2006; Çelik and Balki 2007; Cataluña, et al. 2008; Demirbas, 2009; Çanakçı et al. 2009; Hazar and Aydın 2010; Rakopoulos, et al. 2011; Tangöz 2017; Hu et al. 2009; Lakshmanan, and Nagarajan, 2011; Korakianitis, et al. 2011; Baskar, and Aiswarya, 2016; Calam et al. 2015; Emiroğlu and Şen 2018). It is observed that vegetable and animal oils are more suitable for diesel engines than these alternative fuels, and therefore studies on their use in diesel engines have increased (Kalam, and Masjuki, 2004; Altun et al. 2008; Nwafor,2003; Chauhan, 2010).

Vegetable oils are advantageous compared to other alternative fuels because they are renewable, have low emissions resulting from combustion, contain almost no sulfur elements, and can be used without modification in engines (Altun et al. 2008; Ozel et al. 2020). Because of these and other advantages seen as a major source of renewable energy, vegetable oils of high viscosity, high density, and boiling point due to various disadvantages such as low volatility for long-term use is not suitable without any improvement in internal combustion engines (Rakopoulos, 2011; Ulusoy et al 2013; Meher, et al. 2006). Long-term use in the case of the formation of carbon residues in the injectors and in the combustion chamber and, as a result, the piston compression of the vessels, clogging of the fuel filter, the deformation of the rubber gasket, bad fuel atomization in the cylinder walls and the unburned engine lubrication oil causes thinning of the oil mingling with (Nwafor, 2003; Meher, et al. 2006; Klimkiewicz, et al. 2013).

In order to prevent these problems caused by using vegetable oils directly in the engine, the viscosity of the oil must be reduced (Nwafor, et al. 2003). Generally investigated methods for lowering the viscosity of these oils are mixing, heating and re-esterification with fuel (Hazar and

Aydın 2010; Nwafor, 2003). In this study, olive pomace oil, sunflower oil and waste frying oil, which are renewable sources, were used by creating a mixture with fuel in certain proportions. The oil used as waste frying oil in this study is the frying oil used for cooking purposes at high temperatures and the edible oils mixed into kitchen waste. A lot of waste oil is produced every day in homes, restaurants, food processing industry and fast food stores around the world (Sanjid, et al 2013).

It is possible to summarize the outstanding studies on the use of vegetable oils in internal combustion engines without any improvement as follows; Schlick et al. (1988), in their study unrefined sunflower oil and soybean oil no.2 used in a naturally aspirated, three-cylinder, direct injection diesel engine by volumetric mixing with diesel fuel. Power output, thermal efficiency and lubrication oil data were examined and the results were satisfactory. After a long 200-hour study, it was determined that excessive carbon residues were formed given the general condition of the combustion chamber and fuel injectors. In their study (2000), Karaosmanoğlu et al. tested sunflower oil in a single cylinder air-cooled diesel engine for 50 hours under partial load conditions. During the engine tests performed with sunflower oil, no significant problems were encountered. At the end of the study, it was stated that sunflower oil could be an alternative candidate for diesel fuel.

In their study, Canakci et al. (2009) tested simple sunflower oil (PCSO) heated in a naturally aspirated front combustion chamber diesel engine. They compared the combustion and emission characteristics of pure sunflower oil with that of petroleum-based diesel fuel (PBDF). They found that in the case of PCSO use at a temperature of 75 ^{o}C, the cylinder gas pressure and heat release curves are similar to PBDF. Compared to PBDF, it has been stated that the ignition delay for PCSO is longer and the start of spray time is earlier. There was a 1.36% decrease in average brake torque for the PCSO. With PCSO use, CO_2, soot and unburned HC emissions decreased, while CO emissions increased by insignificant amounts.

In their study, Yu et al. (2002) investigated the effect of waste frying oil on engine performance, combustion analysis, and exhaust emissions. The uncontrolled combustion phase was found to be less intense than working with diesel fuel due to shorter ignition delay if waste frying oil was used. Due to the lower combustion volume, the peak pressure of waste frying oil was 1.5 bar higher and 1.1-3.8 degrees earlier than diesel. Compared to diesel fuel, CO, NO and SO_2 emissions obtained from waste frying oil were higher.

Nanthagopal and Subbarao (2009) conducted research on the emission and performance characteristics of direct-jet diesel engine emulsion of waste frying oil and diesel fuel with different proportions of water (10%, 20% and 30%). NOx and CO emissions were reduced by increased water content in waste frying oil-diesel fuel emulsion. Compared to diesel fuel, there was an increase of approximately 2.78% in brake thermal efficiency with a water content of 20%. As a result of the experimental study, it was stated that 20% water content gave optimum results.

Capuano et al (2017) in their comprehensive review of direct use of waste vegetable oils (WVO) in internal combustion engines, it was found that in general, WVO offers longer ignition delays, increases in specific fuel consumption as well as decreased engine efficiency, lower torque and power due to lower thermal value of WVO, and increased exhaust gas temperature with use of WVO. Polluting emissions co, HC, NOx, SO_2, CO_2 and soot emissions from which conflicting results are obtained, but on average; There was an increase in CO and HC emissions and a decrease in $_{CO2}$ emissions when WVO was used. It has been stated that NOx and PM emissions are significantly affected by measurement systems and that the presence of oxygen in fat molecules and the absence of aromatic compounds tend to create NOx.

Bari et al (2004) investigated the effect of using waste frying oil in a direct injection engine at different fuel firing Times on combustion, performance and emissions and compared the results with diesel fuel. They found that waste frying oil and diesel fuel had similar reactions to the change in ignition advance. It has been stated that combustion starts early with early ignition timing for both fuels and higher peak pressures are reached at earlier crankshaft angles. The timing of ignition 4 degrees earlier resulted in better engine performance and 1.1% higher brake thermal efficiency was achieved with 1.6% diesel fuel with waste frying oil, CO emissions decreased by 9.9% with WCO and 44.9% with diesel fuel, but NOx emissions increased by 76.6% with WCO and increased by 91.4% with diesel fuel. In all operating situations, WCO was found to have a shorter ignition delay than diesel fuel, but it was stated that the ignition delay obtained when working with WCO compared to diesel fuel was more sensitive to engine load and ignition time.

In their study, Kalam et al (2011) used the waste palm oil and the waste coconut oil in a diesel engine by mixing 5% of it into diesel fuel, examining engine performance and exhaust emissions. By using 5% waste palm oil and waste coconut oil mixtures, brake power was reduced by 1.2% and 0.7%, respectively, compared to diesel fuel. There has also been a reduction in HC, is, CO and NOx emissions with both waste frying oil mixtures. Kumar et al. (2014) investigated the effect of the use of waste frying oil and waste frying oil emulsion on engine performance, exhaust emissions, and combustion in a single-cylinder water-cooled diesel engine. HC, CO and soot emissions have increased in the case of waste frying oil use. A significant reduction in all emissions was achieved by WCO emulsion. In-cylinder maximum pressure and maximum pressure increase speed were found to be higher with WCO emulsion compared to plain WCO, especially at high power outputs. Ignition delay was found to be higher with WCO and WCO emulsion than with diesel fuel. Corsini et al. (2016) conducted work on the use of different ratios of diesel fuel waste frying oil (WCO) mixtures in the four-cylinder common rail diesel engine. The results of the study were compared with the values obtained in diesel and WCO use. Engine torque and efficiency deteriorated with the use of WCO, the biggest difference between diesel fuel and WCO.

Olive pomace oil the literature on the effect on engine performance and exhaust emissions study of biodiesel and olive pomace oil is converted into fuel where fuel properties are generally improved, then simple diesel fuel with biodiesel or a mixture in certain proportions observed by creating engines that can be used in (Çaynak et al. 2009; Yücel 2011; Redel-Macías, et al. 2012a; Redel-Macías, et al. 2012b; López, et al. 2014; López, et al. 2016; Dodos 2017).

As is known, many motorcycle engines, water engines, tree saw engines etc. the engines are two-timing. These engines do not have a separate lubrication system as in four-stroke engines and the process of lubricating the engine is carried out by mixing the engine oil into the fuel at certain rates. Self-aspirated water pump was used in the study. The water pump is powered by a two-stroke, carbureted, naturally aspirated gasoline engine. The two-stroke engine used by the manufacturer is recommended to use pre-mixed gasoline as fuel. Fuel mixture (fuel/oil) is limited by the manufacturer to 1/50 and 1/25 ratio (Anonim 2020).

When the literature studies were examined, it was observed that alcohols were generally used as alternative fuels in Spark Plug-fired engines, and that there were limited studies on the use of mineral oil and vegetable oils as direct fuel additives (Kumar, 2012; Senthilkumar, 2015). In this study, a single-cylinder, carbureted, spark plug-fired, two-stroke gasoline engine used in agricultural irrigation was used. This engine's fuel by volume in 1/20 (5% oil - 95% gasoline) and 1/10 (10% oil - 90% gasoline) in the rates of two-stroke engine oil and various vegetable oils (crude olive pomace oil, refined olive pomace oil, crude sunflower oil, refined sunflower oil and waste cooking oil) mixed, fuel consumption, exhaust emissions, change the amount of wear on piston rings compression was investigated. For the examination of the amount of wear in the compression ring, the engine was operated in 50-hour and 100-hour periods with each yolk and 1. the amount of wear on the compression ring has been determined.

2. Material and Method

The engine experiments were carried out with a single cylinder, spark plug-fired, carbureted, two-stroke petrol Oleo-Mac model SA 45 engine. A centrifugal water pump connected to the crankshaft provided the engine to operate under load. Centrifugal pumps are generally used for the extraction of liquids. During this process, the desired power is provided from the internal combustion engine in general in regions where there is no electrical possibility. As is known, the power given to the fluid by the pump varies depending on the density of the fluid, the height of the fluid pulling or pressing, and the flow rate (Korkmaz 2015).

During the experiments, the water pump was provided to press and pull water from a height of 5 meters. In this way, the water pump connected to the engine is operated under load during pressing and pulling of the water. In order to calculate the power values in the experiments and to make comparisons, the filling time of a water container with a volume of 50 liters was taken into account each time. Before the experiments, the engine was started and expected to reach operating temperature. When the engine reaches its operating temperature, the pump part of the engine is submerged in the water and the water is drawn. With the withdrawal of water, the engine started to load, the centrifugal pump air intake operations were done and the pump and engine were provided to operate in a fixed regime. After this stage, the output pipe of the pump was left in the empty container of 50 liters and the filling time of the container was recorded with the stopwatch. In the meantime, the engine speed was measured by a laser speedometer over the engine crankshaft. The flow rate of the water pump was calculated by taking note of the data obtained. The experiments were repeated three times in each fuel mixture to determine the flow rate measurement value. The experiments were first started using standard fuels such as gasoline-engine oil mixtures. The obtained values were based on and the calculated flow rate values were tried to be reached in all studies. For this reason, the position of the gas arm was changed and the experiments were repeated. Thus, a fixed load design was created and the effects of different fuel mixtures could be studied by capturing the same conditions. The data obtained is graphed and examined in the discussion section. The schematic picture of the experiment is given in Figure 1. The characteristics of the experiment engine and centrifugal pump are given in Table 1.

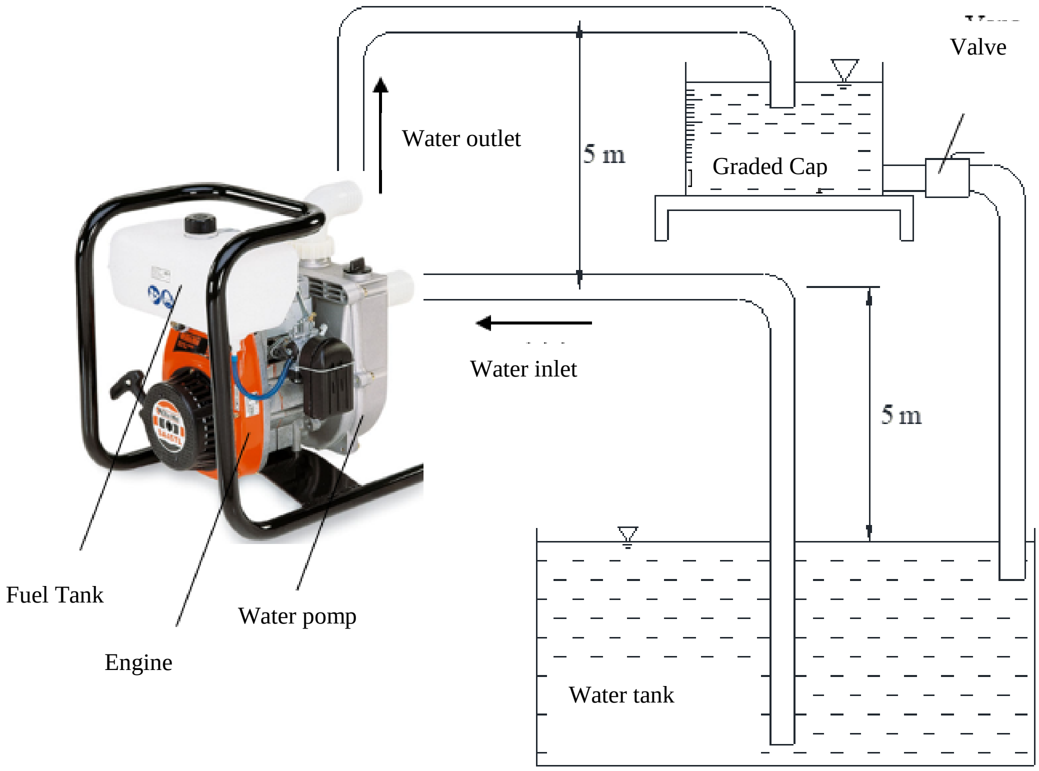


Figure 1. Schematic view of the test setup

Table 1. The features of the test motor and the centrifugal pump

Brand	**Oleo-Mac SA 45**
Engine Power (HP)	3.4
Cylinder Volume (cm^3)	98.2
Fuel Tank Capacity (l)	2.7
Pump Type	Centrifugal
Suction and Discharge Pipe Diameter (mm)	50.8
Intake Depth (m)	7.5
Pressure Height (m)	40
Maximum Flow Rate (l/sn)	9.6

The flow of water is an important parameter used in calculating motor power. Therefore, the flow rate was calculated using Equation 1 from the filling time of the tank determined by the stopwatch.

$$Q = \frac{V}{t}\left(\frac{m^3}{h}\right) \quad (1)$$

In the flow rate calculation, V is the volume of the container (m^3) and t is the filling time of the container (h). Water pumps absorb liquid fluid from a certain height during operation and carry water by pressing it in a pressurized manner to a certain height. During this process, a job is done and energy is wasted. The work done by the motor in unit time during the displacement of water (W) is calculated by Equation 2 (Vedat et al. 2009).

$$G\ddot{u}\c{c} = \rho . g . Q . Hm \ (W) \qquad (2)$$

Here, ρ refers to the density of the fluid (kg/m^3), g refers to the gravity acceleration (m/s^2), Q refers to the flow rate (m^3/s), Hm refers to the pressure height (m) of the fluid. In these calculations, all losses are ignored.

In two-stroke engines, lubrication is provided by lubricating oils added to the engine fuel. Therefore, both the fuel and the lubricating oil added to it are burned by the engine. The experimental study of motor oil (EO), crude olive pomace oil (CPO), refined olive pomace oil (RPO), crude sunflower oil (CSO), refined sunflower oil (RSO) and waste cooking oil (WCO) motor fuel by volume in 1/20 (5% oil-95% gasoline) and 1/10 (10% oil-90% gasoline) mixing ratios for the fuel blends used in the experiments were obtained. The engine was first operated in accordance with normal operating conditions by using engine oil/gasoline mixtures of 1/20 (5% oil-95% gasoline) and 1/25 (4% Oil-96% gasoline) in volumetric proportions. Later experiments with fuel mixtures created with CPO, RPO, CSO, RSO and WCO were repeated. In the second part of the experiments, the engine was subjected to a long-term operation regime of 50 and 100 hours in order to determine the condition of the segments. This was done when the engine was under load. Experiments were repeated with each fuel mixture exposing the engine to 50-and 100-hour operating hours. At the start of each experiment, all segments of the engine (oil and compaction ring) were renewed. In order to detect wear on the Rings, The Rings were weighed separately before and after Operation. At the end of the experiment, the engine was dismantled, 1. the wear condition of the compression ring was examined. All delusions on the ring have been cleared before starting the weighing process. Afterwards, the ring was measured with a precision scale and the amount of wear was determined. It is filtered before frying and using raw oils and heated by stirring for 15 minutes at 110 °C temperature against the water that may be in the body. In addition of oil to gasoline, isopropyl alcohol is added to the mixture at a rate of 1% by volume to ensure that the oil is completely dissolved in gasoline. Table 2 gives the main physical and chemical properties of isopropyl alcohol. The ratios and abbreviations of the mixtures used in the experiments are detailed in Table 3.

Table 2. Physical and chemical properties of isopropyl alcohol (Aksoy and Bayrakçeken 2010)

Chemical Formula	Mole Mass (g/mol)	Kinematic Viscosity 25 °C (mm^2/s)	Density 20 °C (g/cm^3)	Thermal Value (kJ/kg)	Boiling Point (°C)	Flash Point (°C)	Ignition Temperature (°C)
C_3H_7OH	60.1	1.96	0.786	33130	82.04	12	425

Table 3. Volume ratios and abbreviations of fuel mixtures

The Type of Oil	**Gasoline Content (%)**	**Fat Content (%)**	**Abbreviation**
Engine Oil	95	5	EO5
	90	10	EO10
Raw Oil Pomace Oil	95	5	CPO5
	90	10	CPO10
Refined Oil Pomace Oil	95	5	RPO5
	90	10	RPO10
Raw Oil Sunflower Oil	95	5	CSO5
	90	10	CSO10
Refined Oil Sunflower Oil	95	5	RSO5
	90	10	RSO10
Waste Frying Oil	95	5	WCO5
	90	10	WCO10

The fuel consumption value of the engine was determined using a precise scale and stopwatch. Emissions were measured from the exhaust pipe output when the engine was running stable. The exhaust emission values are recorded by measuring them with the ITALO plus exhaust gas analyzer, given the measurement range in Table 4. The physical and chemical properties of the oils used in the study are given in Table 5.

Table 4. Properties of the ITALO PLUS exhaust gas analyzer

Measurement	Measurement Range	Sensitivity
CO (vol. %)	0-10.00	±0.06%
CO_2 (vol. %)	0-20.00	±0.5%
NO*x* (ppm)	0-2000	±5
HC (ppm)	0-50000 n-hexan	±12
O_2 (vol. %)	0-21	±0.1%
Soot (%)	0-20	±0.1%

Table 5. Chemical and physical properties of oils (Avcıoğlu et al. 2011; Öğüt and Oğuz 2011; Wang et al. 2019)

Fuel	Kinematic Viscosity (mm^2/s)	Density (g/cm^3)	Thermal Value (MJ/kg)
Gasoline	-	0.74	44.3
Engine Oil	14	0.892	39.6
Raw Oil Pomace Oil	122.8	0.99	37.6
Refined Oil Pomace Oil	83.5	0.92	36.9
Raw Oil Sunflower Oil	44.6	0.98	36.44
Refined Oil Sunflower Oil	34.2	0.92	38.42
Waste Frying Oil	28	0.99	35.6

3. Result and Discussion

In two-stroke engines, lubrication is carried out by mixing certain amounts of engine oil into the fuel. According to the standard gasoline-engine oil mixture in this study, fuel consumption of alternative oil mixtures to gasoline, NOx, soot, HC, CO, CO_2 emissions and Engine 1. the effects of compression tab wear were examined and presented in graphs and the effects were compared.

Fuel consumption indicates the amount the engine consumes after one hour of operation. The effect of the oils added to the gasoline by volume on fuel consumption is shown in Figure 2. In all fuel mixtures, fuel consumption was increased along with the increase in the ratio of oil added to gasoline. As shown in Table 5, the thermal values of vegetable oils are lower than both motor oil and gasoline. Therefore, the total heat value of the mixture decreased with the increase of the oil ratio in the mixture and more fuel is needed to do the same work was seen with the measurements made. WCO5 and WCO10 mixtures are the two fuel mixtures with the lowest total heat value. As shown in Figure 2, the highest fuel consumption values occurred with the use of these two fuel mixtures. One of the important parameters affecting combustion in Spark Plug fired engines is the fuel/air mixture ratio. Studies report that the fuel/air ratio varies with the density and viscosity of fuels in vegetable oil use (Avcıoğlu et al. 2011). In addition to the thermal value, it is thought that the increased density and viscosity value relative to gasoline may also lead to increased fuel consumption values. All fuel mixture ratios increase in fuel consumption compared to EO5 and EO10 fuel. The highest rate of increase in fuel consumption is 41.5% with WCO5 fuel and 45.4% with WCO10 fuel mixture. Similar studies in internal combustion engines also reported an increase in fuel consumption values with the use of vegetable oil (Awad et al. 2019).

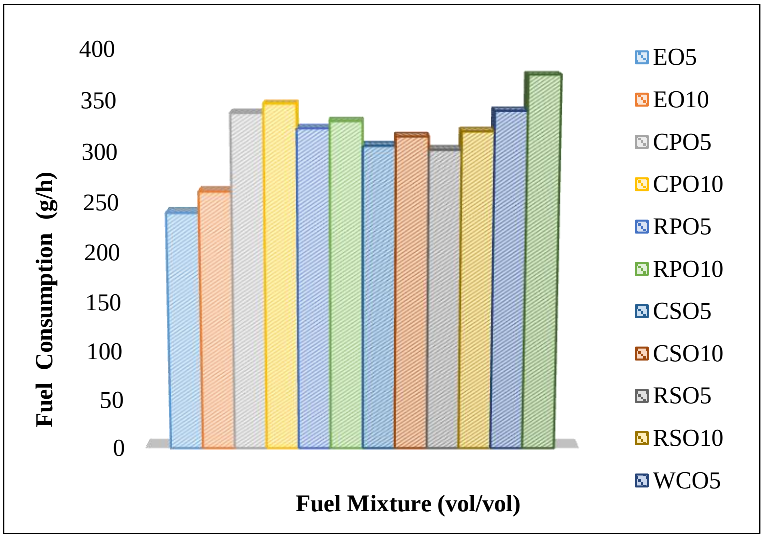


Figure 2. Effect of oil addition on fuel consumption

Figure 3 shows the effect of adding oil to gasoline on nitrogen oxide (NOx) emissions. NOx emissions are generally known to consist of nitrogen monoxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O) (Kutlar et al. 1998). The formation of NOx emissions is related to the presence of oxygen during the combustion process as well as the temperature and reaction time of the combustion reaction (Kutlar et al. 1998). In general, NOx emissions in gasoline engines are virtually nonexistent. As shown in Figure 3, NOx emissions tend to decrease in the ratio of each oil mixture with the addition of oil into the gasoline. Overall, the percentage value of the oil in the mixture increased along with the amount of reduction in NOx emissions. This situation is thought to change due to the reduction of the thermal value of the fuel. NOx emissions of 48 ppm and 58 ppm with EO5 and EO10 fuel mixtures were measured at levels 18 and 21 ppm with CSO5 and CSO10 fuel mixtures. The lowest NOx emission value was achieved with CSO10 fuel mixture value. In general, there are not many studies where vegetable oil additives are used in gasoline engines.

However, there are many studies that report that NOx emissions decrease in parallel with the decrease in thermal value. The results are similar to the (Maria et al. 2016) study in the literature.

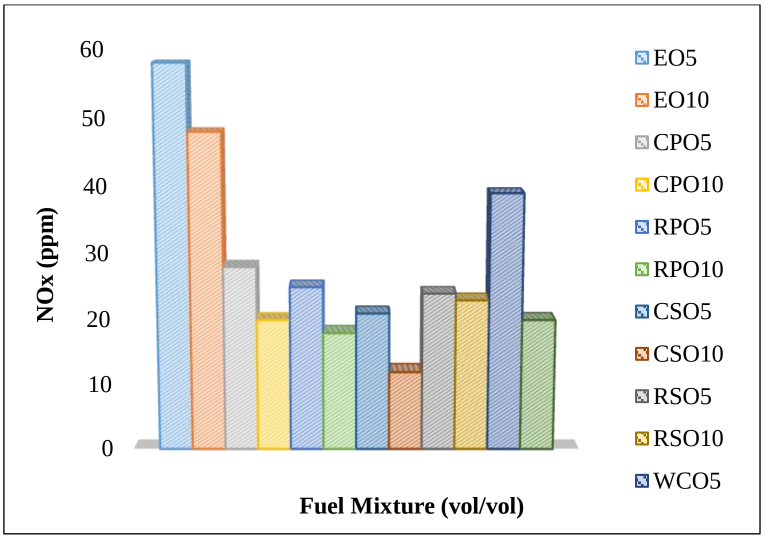


Figure 3. Effect of oil addition to the gasoline on NOx emissions

The change in soot emissions by adding oil to gasoline is shown in Figure 4. Soot emission is defined as the presence of carbon particles in the exhaust gas as a result of incomplete combustion (Kumar et al. 2006). Soot emissions in gasoline engines are ignored and not measured in many studies. However, in this study, it was decided to measure soot emission values by adding oil to the engine fuel and taking into account the use of vegetable oil in experiments. When Figure 4 was examined, soot emissions were increased in all fuel mixtures with the addition of oil into gasoline. The highest is emission increase was measured at 22% by the wco10 fuel mix. This increase value represents an increase of about 300% over the EO10 fuel mixture. The highest is emission increase was achieved with the WCO10 fuel mixture and the lowest emission value was achieved with the RPO5 fuel mixture. It is possible to express the factors that cause the increase of soot emission with the bifurcated bond structure of vegetable oils, viscosity and density values. Studies conducted with the use of vegetable oils indicate that the tendency to produce soot emission increases according to the bond structure of oils (Öğüt and Oğuz 2011). The results of the study are similar to the literature (Alessandro, et al. 2019).

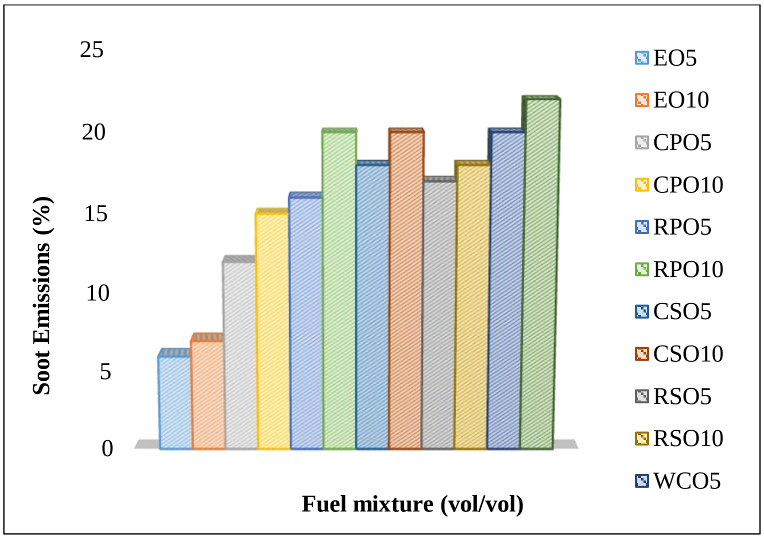


Figure 4. Effect of oil addition to the gasoline on soot emissions

Figure 5 shows the effects of oils added to gasoline on hydrocarbon (HC) emissions. HC emissions are defined as the emissions that occur as a result of the failure of the fuel in gasoline engines. Two-stroke engines do not have an engine lubrication system. Therefore, the lubrication process is realized by adding the engine oil to the gasoline. As shown in Figure 5, HC emissions increase at each mixture rate with the amount of oil added to the gasoline. It is thought that the failure of vegetable oils added to the engine oil to burn fully in the cylinder caused the increase in HC emissions. In addition, the excess of in-cylinder leaks in two-stroke engines is an important effect that leads to an increase in HC emissions. As is known, the addition of vegetable oil to gasoline increased the amount of fuel consumption. The increase in the amount of fuel taken into the cylinder led to an increase in HC emissions from the cylinder. The highest amount of increase in HC emissions was achieved in the WCO10 fuel mixture. HC emissions of 7 ppm with EO10 engine oil increased to 22 ppm with WCO10 fuel mixture. The results are similar to the literature (Alander, 2005).

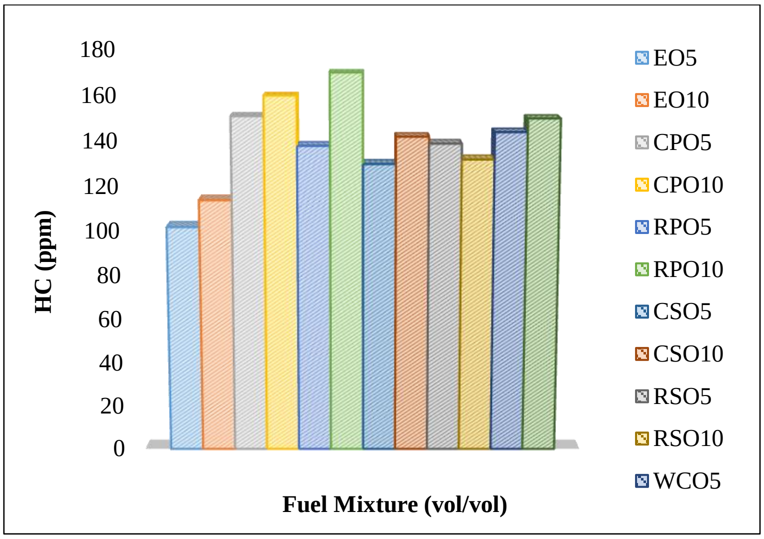


Figure 5. Effect of oil addition to the gasoline on HC emissions

Figure 6 shows the effects of added oils on carbon monoxide (CO) emissions. CO emissions among combustion products result from insufficient oxygen (O_2) in the environment. In this case, all of the carbon in the fuel cannot be converted into CO_2 emissions and remains as CO emissions (Vedat et al. 2009). As shown in Figure 6, there is an increase in CO emissions in all fuel mixture ratios along with the amount of vegetable oil added to the gasoline. Because of the high viscosity and density values of vegetable oils, it is thought that the fuel/air mixture within the cylinder is far from ideal and causes the combustion to partially worsen, which in turn causes the increase of CO emissions. The lowest value in CO emissions was achieved by the CPO5 fuel mixture. The highest CO emissions were achieved when using RSO fuel mixtures. The results of the study are similar to the literature (Zulfattah, et al. 2019).

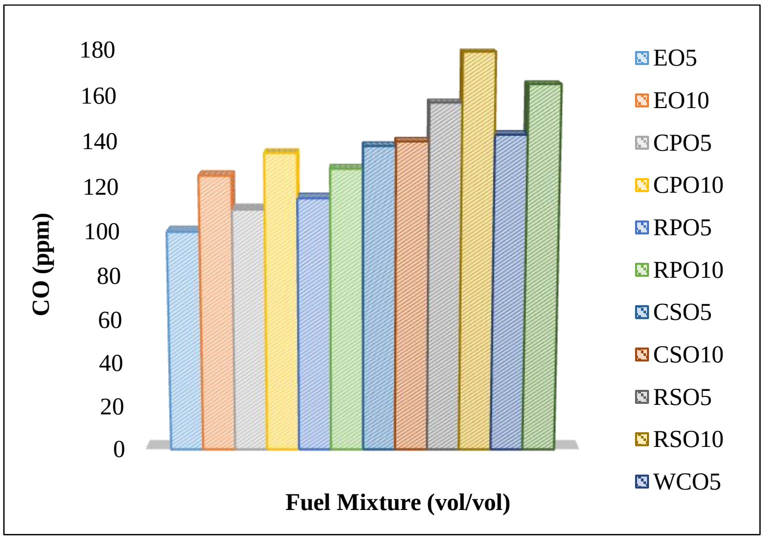


Figure 6. Effect of oil addition to the gasoline on CO emissions

Figure 7 shows the change in carbon dioxide (CO_2) emissions according to the amount of oil added to gasoline. CO_2 emission refers to regular combustion in the cylinder. It is observed that CO_2 emissions are reduced with the addition of vegetable oil into gasoline. To express this situation you will need to look at Figure 6. It is stated in the previous section that the combustion is partially worsened with the addition of vegetable oil and the complete combustion in the cylinder cannot be performed. Therefore, CO_2 emissions are expected to decrease. The highest CO_2 emission value was measured at 25 ppm with the EO 10 fuel mixture. The lowest CO_2 emissions were measured at 10 ppm of RPO10 fuel mixture. The results were found to be in harmony with the literature (Yusoff, et al. 2017).

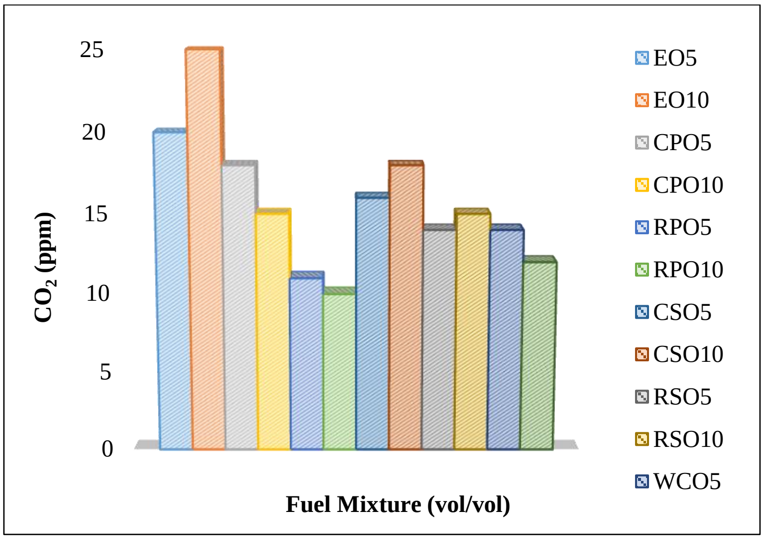
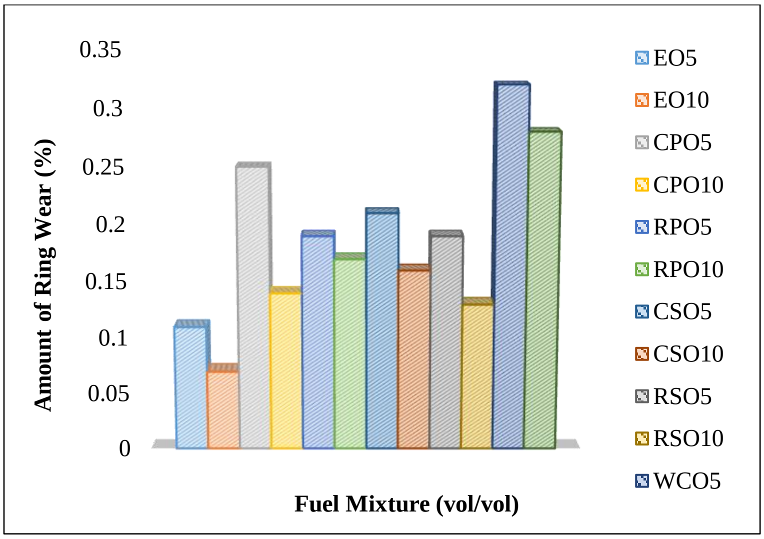


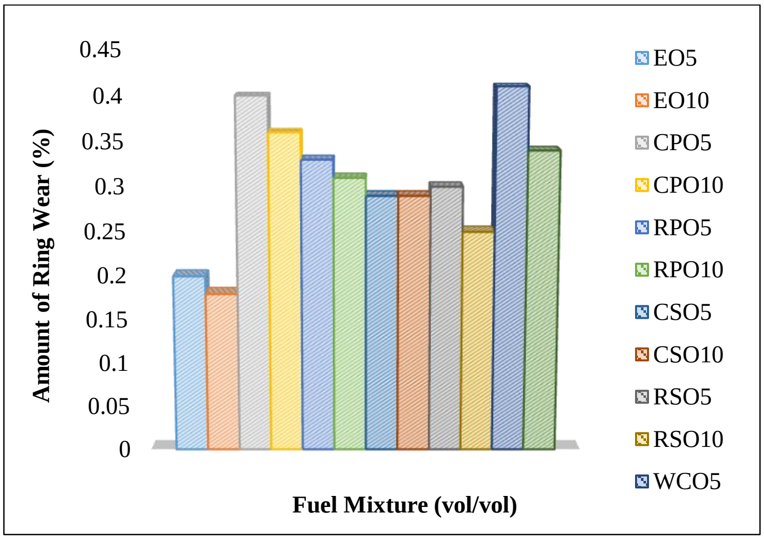
Figure 7. Effect of oil addition to the gasoline on CO_2 emissions

Figure 8 shows the effect of oil added to gasoline on Ring wear after 50 and 100 hours of operation. Ring wear is an important parameter affecting the power of the engine. Wear can occur when the segments are not fully lubricated due to the reasons such as leaving soot and soot of the fuel used in the engine, viscosity of the lubricating oil, failure of the others to give the desired performance according to sufficient and temperature. Compared to the vegetable oils used with motor oil, there was an increase in the amount of wear in all fuel mixtures. Vegetable oils consist of chains of three fatty acid molecules bonded to a glycerol molecule called triglycerides. Fatty acids differ in each vegetable oil with different chain lengths and double bonds (Aksoy et al. 2010). These differences cause the lubricating properties of oils to change. While the excess amount is more at low mixture rates, the amount of oil added to the mixture decreases partially with the increase. The rate of increase in the amount of wear increased as the Working Time increased from 50 hours to

100 hours. As the amount of soot and soot accumulated on the Rings increases during long working periods, the amount of wear is expected to increase as a result of the failure of lubricating oils to enter between the Rings. After 50 hours of operation, the highest amount of wear along with vegetable oil was obtained with the WCO5 fuel mixture. The minimum amount of wear was obtained by RSO10 fuel mixture. The highest amount of wear after 100 hours of operation was achieved with the WCO5 fuel mixture. The results are similar to the literature (Zulfattah, 2019).



(a) 50 hours of work



(b) 100 hours of work

Figure 8. Effect of oil added to gasoline on ring wear

4. Conclusion

In this study, the effects of different fuel mixtures on engine emissions, engine performance and engine parts in a two-stroke engine were examined and the following results were reached:

1. With the addition of vegetable oil, increased fuel consumption was observed in all mixtures. The highest fuel consumption value was achieved in WCO mixtures. A fuel consumption value of 340 gr/h was determined in the WCO5 fuel mixture and 375 gr/h in the WCO10 fuel mixture. These values were found to be 41.6% and 43.5% higher than EO5 and EO10 fuel, respectively.
2. NOx emissions were reduced in all fuel mixtures with the addition of vegetable oil. The highest reduction in emissions was achieved by CSO fuel mixtures. NOx emissions measured at 21 ppm with the CSO5 fuel mixture decreased to 10 ppm with the use of the CSO12 fuel mixture. NOx emissions decreased by 63.8% compared to EO5 fuel mixture when CSO5 fuel mixture was used and NOx emissions decreased by 75% when CSO10 was used.
3. There has been an increase in soot emissions in all fuel mixtures. The highest rate of increase was achieved by WCO fuel mixtures. Soot emissions reached 20% with WCO5 fuel and 22% with WCO10 fuel. An increase of 214% compared to EO5 fuel by using the WCO5 fuel mixture and 233% compared to EO10 fuel mixture by using the WCO10 fuel mixture was detected.
4. All fuel mixtures show an increase in CO emissions. The highest rate of increase was measured by the use of RSO fuel mixtures. With the use of the RSO5 fuel mixture, the CO emission measured at 157 ppm increased to 179 ppm with the use of the rso10 fuel mixture. The increase in CO emissions was 37% compared to the EO5 fuel mixture and 79% compared to the EO10 fuel mixture.
5. All fuel mixtures show a reduction in CO_2 emissions. The highest amount of reduction was achieved by using RPO fuel mixtures. CO_2 emissions measured at 20 ppm by using the EO5 fuel mixture decreased to 11 ppm by using the RSO5 fuel mixture, and 25 ppm by using the EO10 fuel mixture by using the RO10 fuel mixture by up to 10 ppm. The amount of CO_2 emissions decreased by 45% compared to the EO5 fuel mixture, while the EO10 fuel mixture decreased by 60%.
6. With the use of the EO10 fuel mixture at the end of 50 hours of operation of the engine, the amount of mass reduction in the segments was 0.7%, while the amount of mass reduction was 0.11% with the use of the EO5 fuel mixture. The lowest amount of wear was achieved in RSO fuel mixtures.

7. After 100 hours of operation of the engine, with the use of the EO10 fuel mixture, the amount of mass reduction in the segments was 0.18%, while the amount of mass reduction was 0.2% with the use of the EO5 fuel mixture. Despite the long use, RSO is still the fuel mixture where the amount of wear is minimal.

As a result of this experimental study, it was concluded that different renewable oils could be used as a direct fuel mixture in two-stroke engines and could be commercially evaluated.

References

Alander, T., Antikainen, E., Raunemaa, T., Elonen, E., Rautiola, A. and Torkkell, K., (2005). Particle emissions from a small two-stroke engine: effects of fuel, lubricating oil, and exhaust aftertreatment on particle characteristics, *Aerosol Sci. Technol*., 39, 151–161.

Aksoy, F. and Bayrakçeken, H., (2010). Dizel Yakıtına %5 ve %10 İzopropil Alkol (IPA) İlavesinin Motor Performans ve Emisyonlarına Etkisi, *Electronic Journal of Vehicle Technologies (EJVT)*, 2(3), 37-43.

Alessandro, A. Z., Ricardo, S. B., Fausto, F., François, M., Marcos, O. G., Massimo, C. and Covadonga, A., (2019). Reducing the exhaust emissions of unregulated pollutants from small gasoline engines with alkylate fuel and low-ash lube oil, *Environmental Research*, 170, 203-214.

Altun, Ş., Bulut, H. and Öner, C., (2008). The comparison of engine performance and exhaust emission characteristics of sesame oil–diesel fuel mixture with diesel fuel in a direct injection diesel engine, *Renewable Energy*, 33, 1791–1795.

Avcıoğlu, A.O., Türker, U. and Atasoy, Z.D., (2011) Tarımsal Kökenli Yenilenebilir Yakıtlar, Nobel Yayın Dağıtım.

Awad, O.I., Mamat, R., Ibrahim, T.K., Kenner, M., Kadirgama, K., Leman, A.M. and Saiful, A.I.M., (2018). Effects of fusel oil water content reduction on fuel properties, performance and emissions of SI engine fueled with gasoline -fusel oil blends, *Renewable Energy*, 118, 858-869.

Baskar, G. and Aiswarya, R., (2016). Trends in catalytic production of biodiesel from various feedstocks, *Renewable and Sustainable Energy Reviews*, 57, 496–504.

Bari, S., Yu, C.W. and Lim, T.H., (2004). Effect of Fuel Injection Timing with Waste Cooking Oil as a Fuel in a Direct Injection Diesel Engine, *Proc. Instn Mech. Engrs Part D: J. Automobile Engineering*, 2168, 93-104.

Capuano, D., Costa, M., Fraia, S.D., Massarotti, N. and Vanoli, L., (2017). Direct use of waste vegetable oil in internal combustion engines, *Renewable and Sustainable Energy Reviews*, 69, 759–770.

Chauhan, B.S., Kumar, N., Jun, Y.D. and Lee, K.B., (2010). Performance and emission study of preheated Jatropha oil on medium capacity diesel engine, *Energy*, 35, 2484-2492.

Calam, A., Solmaz, H., Uyumaz, A., Polat, S., Yilmaz, E. and İçingür, Y., (2015). Investigation of usability of the fusel oil in a single cylinder spark ignition engine, *Journal of the Energy Institute*, 88, 258-2654.

Cataluña, R., da Silva, R., de Menezes, E. W., and Ivanov, R. B., (2008). Specific consumption of liquid biofuels in gasoline fuelled engines, *Fuel*, 87(15), 3362-3368.

Corsini, A., Antonio, R.D., Nucci, G.D., Marchegiani, A., Rispoli, F. and Venturini, P., (2016). Performance analysis of a common-rail Diesel engine fuelled with different blends of waste cooking oil and gasoil, *Energy Procedia*, 101, 606–613.

Canakci, M., Ozsezen, A.N., Turkcan, A., (2009). Combustion analysis of preheated crude sunflower oil in an IDI diesel engine, *Biomass and Bio Energy*, 33, 760–767.

Çaynak, S., Gürü, M., Biçer, A., Keskin, A. and İçingür, Y., (2009). Biodiesel production from pomace oil and improvement of its properties with synthetic manganese additive, *Fuel*, 88, 534-538.

Çelik, M.B. and Balki, M.K., (2007). Düşük güçlü bir motorda farklı sıkıştırma oranlarında lpg kullanımının performans ve emisyonlara etkisi, *J. Fac. Eng. Arch. Gazi Univ*., 22(1), 81-86.

Çelik, M. B., Özdalyan, B., Alkan, F., (2011). The use of pure methanol as fuel at high compression ratio in a single cylinder gasoline engine, *Fuel*, 90(4), 1591-1598.

Demirbas, A., (2009). Biodiesel from waste cooking oil via base-catalytic and supercritical methanol transesterification, *Energy Conversion and Management*, 50, 923–927.

Dodos, G.S., Tsesmeli, C.E. and Zannikos, F., (2017). Evaluation of the antimicrobial activity of synthetic and natural phenolic type antioxidants in biodiesel fuel, *Fuel*, 209, 150-161.

Emiroğlu, A.O. and Şen, M., (2018). Combustion, performance and emission characteristics of various alcohol blends in a single cylinder diesel engine, *Fuel*, 212, 34-40.

Hazar, H. and Aydin,H., (2010). Performance and emission evaluation of a CI engine fueled with preheated raw rapeseed oil (RRO)–diesel blends, *Applied Energy*, 87, 786–790.

Hu, E., Huang, Z., Liu, B., Zheng, J., Gu, X. and Huang, B., (2009) Experimental investigation on performance and emissions of a spark-ignition engine fueled with natural gas–hydrogen blends combined with EGR, *International Journal of Hydrogen Energy*, 34, 528–539.

Kalam, M.A. and Masjuki, H.H., (2004). Emissions and deposit characteristics of a small diesel engine when operated on preheated crude palm oil, *Biomass and Bioenergy*, 27, 289-297.

Kalam, M.A., Masjuki, H.H., Jayed, M.H. and Liaquat, A.M., (2011). Emission and performance characteristics of an indirect ignition diesel engine fuelled with waste cooking oil, *Energy*, 36, 397-402.

Karaosmanoğlu, F., Kurt, G. and Özaktaş, T., (2000). Long term CI engine test of sunflower oil, *Renewable Energy*, 19, 219-221.

Klimkiewicz, M., Mruk, R., Słoma, J. and Wojdalski, J., (2013). The use of raw rapeseed oıl to power the engınes of agrıcultural tractors and vehıcles, *5th International Conference TAE 2013, Trends in Agricultural Engineering*, Prague, 330-334.

Korkmaz, E., (2015). Tek Kademeli Bir Derin Kuyu Pompası Karakteristiklerinin Deneysel Olarak Belirlenmesi, *Suleyman Demirel University Journal of Natural and Applied Science*, 19(1), 1-8.

Korakianitis, T., Namasivayam, A.M. and Crookes, R.J., (2011). Natural-gas fueled spark-ignition (SI) and compression-ignition (CI) engine performance and emissions, *Progress in Energy and Combustion Science*, 37, 89-112.

Kumar, M. S., Kerihuel, A., Bellettre, J and Tazerout, M., (2005). Effect of water and methanol fractions on the performance of a CI engine using animal fat emulsions as fuel, *Proceedings of the Institution of Mechanical Engineers Part A Journal of Power and Energy*, 219, 583-592.

Kumar, M. S., Kerihuel, A., Bellettre, J., and Tazerout, M., (2006). Experimental investigations on the use of preheated animal fat as fuel in a compression ignition engine, *Renewable Energy*, 30, 1443–1456

Kumar, S.M. and Jaikumar, M., (2014). A comprehensive study on performance, emission and combustion behavior of a compression ignition engine fuelled with WCO (waste cooking oil) emulsion as fuel, *Journal of the Energy Institute*, 87, 263–271.

Kumar, G.S., Balamurugan, K., Vinu, S., Radhakrishnan, M. and Senthilprabhu, G., (2012). Tribological and emission studies on two stroke petrol engine lubricated with sunflower methyl ester, *Journal of Scientific and Industrial Research*, 17, 562-565.

Kutlar, O.A., Ergeneman, M., Arslan, H. and Mutlu, M., (1998). Taşıt Egzozundan Kaynaklanan Kirleticiler, Birsen Yayınevi, İstanbul.

Lakshmanan, T., Nagarajan, G., (2011). Study on using acetylene in dual fuel mode with exhaust gas recirculation, *Energy*, 36, 3547-3553

Lopez, I., Pinzi, S., Leiva-Candia, D. and Dorado, M.P., (2016). Multiple response optimization to reduce exhaust emissions and fuel consumption of a diesel engine fueled with olive pomace oil methyl ester/diesel fuel blends, *Energy*, 117, 398-404.

Maria, A. C., Maria, V. P., Salvatore, F., Pietro, S., Daniele, T., Paolo, I., Dario, B. and Adolfo, S., (2016) Performances and emissions of a 4-stroke motorcycle fuelled with ethanol/gasoline blends, *Fuel*, 183, 470-477.

Meher, L. C., Vidya Sagar, D. and Naik, S. N., (2006). Technical aspects of biodiesel production by transesterification-a review, *Renewable and Sustainable Energy Reviews*, 10, 248–268.

Nanthagopal, K. and Subbarao, R., (2009). Experimental investigation and performance evaluation of di diesel engine fueled by waste oil-diesel mixture in emulsion with water, *Thermal Science*, 13(3), 83-89.

Nwafor, O.M.I., (2003) The effect of elevated fuel inlet temperature on performance of diesel engine running on neat vegetable oil at constant speed conditions, *Renewable Energy*, 28, 171–181.

Nwafor, O.M. and Rice, G., (1996). Performance of Rapeseed Oil Blends in a Diesel Engine, *Applied Energy*, 54(4), 345-354.

Öğüt, H. and Oğuz, H., (2011). Biyodizel, Nobel Yayın Dağıtım.

Rakopoulos, D.C., Rakopoulos, C.D., Papagiannakis, R.G. and Kyritsis, D.C., (2011). Combustion heat release analysis of ethanol or n-butanol diesel fuel blends in heavy-duty DI diesel engine, *Fuel*, 90, 1855–1867.

Redel-Macías, M.D., Pinzi, S., Leiva, D., Cubero-Atienza, A.J. and Dorado, M.P., (2012a). Air and noise pollution of a diesel engine fueled with olive pomace oil methyl ester and petrodiesel blends, *Fuel*, 95, 615–621.

Redel-Macías, M.D., Hervás-Martínez, C., Pinzi, S., Gutiérrez, P.A., Cubero-Atienza, A.J. and Dorado, M.P., (2012b). Noise prediction of a diesel engine fueled with olive pomace oil methyl ester blended with diesel fuel, *Fuel*, 98, 280–287.

Sanjid, A., Masjuki, H.H., Kalam, M.A., AshrafurRahman, S.M., Abedin, M.J. and Palash, S.M., (2013). Impact of palm, mustard, waste cooking oil and Calophyllum inophyllum biofuels on performance and emission of CI engine, *Renewable and Sustainable Energy Reviews*, 27, 664–682.

Sakinah, H., Kadirgama, K., Ramasamy, D., Noor, M. M., Amirruddin, A. K., Najafi, G. and Rahman, M. M., (2017). Waste cooking oil blended with the engine oil for reduction of frictionand wear on piston skirt, *Fuel*, 205, 247-261.

Senthilkumar, G., Balamurugan, K. and Mohanraj, J., (2015). Emission characteristics of sunflower oil based bio-compatible blends of 2T oil, *Journal of Scientific and Industrial Research*, 74, 48-51.

Simio, LD., Gambino, M., and Iannaccone, S., (2012). Effect of Ethanol Content on Thermal Efficiency of a Spark-Ignition Light-Duty Engine, *ISRN Renewable Energy*, 2012, 1-8.

Schlick, M.L., Hanna, M.A. and Schinstock, J.L., (1988). Soybean and Sunflower Oil Performance in a Diesel Engine, *American Society of Agricultural Engineers*, 31(5), 1345-1349.

Ozel, S., Vural, E. and Binici, M., (2020). Optimization of the effect of thermal barrier coating (TBC) on diesel engine performance by Taguchi method, Fuel, 263, 116537.

Tangöz, S., Kahraman, N., Akansu, S.O., (2017). The effect of hydrogen on the performance and emissions of an SI engine having a high compression ratio fuelled by compressed natural gas, *International Journal of Hydrogen Energy*, 42, 25766-25780.

Ulusoy, Y., Arslan, R., Kaplan, C. and Bolat, A., (2013). Investigation of engine performance of waste cooking oil as a fuel in diesel tractor engines, *5th International Conference TAE 2013, Trends in Agricultural Engineering*, Prague, 622-626.

URL-1, 2020, http://www.oleo-mac.co.uk/allegati/emakcatalog/MTP_OM_2_2010_B_rev1.pdf, (Erişim Tarihi: 28.01.2020).

Vedat, D., Hüseyin, Y. and Tuncay, G., (2009). Tarımsal Sulamada Kullanılan Pompaların Karakteristik Değerlerinin Laboratuvar Koşullarında Bilgisayar Destekli Olarak Belirlenmesi, *Tarım Makinaları Bilimi Dergisi*, 5(2), 223-234.

Yu, C.W., Bari, S. and Ameen, A., (2002). A comparison of combustion characteristics of waste cooking oil with diesel as fuel in a direct injection diesel engine, *Proc. Instn Mech. Engrs Part D: J. Automobile Engineering*, 216, 237-243.

Yusoff, M.N.A.M., Zulkifli, N.W.M., Masjuki, H.H., Harith, M.H., Syahir, A.Z., Kalam, M.A. and Khuong, L.S., (2017). Performance and emission characteristics of a spark ignition engine fuelled with butanol isomer-gasoline blends, *Transport. Res. Transport Environ*, 57, 23-38.

Yücel, Y., (2011). Biodiesel production from pomace oil by using lipase immobilized onto olive pomace, *Bioresource Technology*, 102, 3977–3980.

Yücel, Y., (2012). Optimization of biocatalytic biodiesel production from pomace oil using response surface methodology, *Fuel Processing Technology*, 99, 97–102.

Zulfattah, Z. M., Zulkifli, N. W. M., Masjuki, H. H., Harith, M. H., Syahir, A. Z., Norain, I., Jumaidin, R., Yusoff, M. N. A. M., Alwi, M. A. and Jamshaid, A., (2019). Effect of bio-based lubricant towards emissions and engine breakdown due to spark plug fouling in a two-stroke engine, *Journal of Cleaner Production*, 221, 215-233.

Quintana, I., C.E., Ruiz, J.J., Cruz-Peragón, F. and Dorado, M.P., (2014). Effect of the use of olive–pomace oil biodiesel/diesel fuel blends in a compression ignition engine: Preliminary exergy analysis, *Energy Conversion and Management*, 85, 227-233.

Wang, L., Wu, Z., Ahmet, A., Badra, A. J., Sarathy, M. S., Loberts, L. W. and Fang, T., (2019). Auto-ignition of direct injection spray of light naphtha, primary reference fuels, gasoline and gasoline surrogate, *Energy*, 170, 375-390.