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Effects of Adding Waste Oil Ethylene Glycol Butyl Ether to Diesel Fuel

Salih Özer[1*] and Cem Cenab Özen[2]

0000-0002-6968-8734, 0000-0002-7671-6473

[1] *Faculty of Engineering and Architecture, Muş Alparslan University, Muş, 049100, Turkey*
[2]*Nuclear Energy and Energy Systems Division., Muş Alparslan University, Muş, 049100, Turkey*

Abstract

This study focuses on the improvement of fuel properties of waste frying oils and their direct use without chemical processing. For this purpose, 10% filtered waste frying oil was added to the diesel fuel. Afterwards, the test fuels were formed by adding 5%, 10% and 20% volumes of Di Ethylene Butyl Glycol Ether to this mixture. The obtained fuel mixtures were run in a diesel engine at a constant engine speed of 3000 rpm at 20%, 40%, 60% and 80% engine loads, and the changes in engine fuel consumption, exhaust gas temperature and ego emissions were investigated. The results showed that all the goose emissions increased with the direct use of waste oil, but the exhaust emissions decreased with the addition of Di Ethylene Butyl Glycol Ether. With the addition of Di Ethylene Butyl Glycol Ether, the viscosity and density values decreased and the heating value increased. The best fuel mixture was obtained with DAGD20 mixture with 20% Di Ethylene Butyl Glycol Ether added. In this fuel mixture, BSFC decreased, Exhaust Gas Temperature increased, NOx increased, CO increased, CO_2 decreased, HC increased, and smoke decreased.

Keywords: Diethylene glycol butyl ether; Exhaust emissions, Diesel engines; Internal combustion engines

Research Article

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* Corresponding author
Salih ÖZER
s.ozer@alparslan.edu.tr
Address: Faculty of Engineering and Architecture, Muş Alparslan University, Muş, 049100, Turkey
Tel:+903122028653

1. Introduction

Academic studies have focused on climate, environment, and energy in recent years. In particular, the opinion that the effects of climate change and global warming are effective on these studies is becoming widespread [1]. In this respect, it is frequently mentioned that less carbon emissions are possible. Recycling is at the very beginning of the business to reduce carbon emissions. Because it has now been proven that recycling and re-evaluation of used products reduce environmental pollution [2].

The most effective way for environmental pollution not to significantly affect the future of humanity and even to reduce this issue from the world agenda is not to zero the demand for oil, but to make the used oils available for the benefit of humanity, albeit in a different area [3]. The reuse of used oils as fuel has become popular today, both as an alternative energy source for humanity and to reduce environmental pollution, by utilizing the energy contained in oils [4].

Using used and inactive oils as an alternative fuel source by passing through different chemical processes has become possible in today's technology and the name of the product obtained is "Biodiesel" [5]. In more technical terms, biodiesel is produced from oilseeds such as canola, sunflower, cotton, soybean, corn and saffron, by the reaction of crude or refined forms of vegetable and animal oils with alcohol (methanol or ethanol) through a catalyst (acidic, basic). is obtained [6]. In 1898, the inventor of the diesel engine, German Rudolph DIESEL, exhibited his engine, which uses peanut oil as a fuel, at the Paris World Fair. This important initiative indicates that vegetable oils will become as important as oil in the future.

In recent years, many studies have been carried out on the direct use of waste oils in diesel engines. These studies can be broadly divided into three parts.

1. Mixing waste oils directly into diesel fuel in such studies, the researchers filtered the waste oil, mixed it into diesel fuel and examined its effects by using it in the engine [7-9]. In these studies, they reported that the high viscosity and density values of the oil had negative effects in general.

2. Use of waste frying oils by converting them to biodiesel. Such studies require complex chemical processes. In these studies, biodiesel was produced by reacting waste oils with alcohol. The obtained biodiesel was used either directly or by mixing it into diesel fuel [10, 11]. It is reported that in such uses, waste oils are burned more efficiently in diesel engines and are environmentally friendly

by reducing exhaust emissions. However, chemical processes' complexity complicates the field of use.

3. It is very common to use waste frying oils by mixing them with alcohol and solvent-type chemicals [12-14]. In this type of use, mixtures are created in different proportions [15, 16]. Studies have reported that this type of use is not as complex as a chemical process. At the same time, since viscosity and density values are reduced with the help of chemical solvents or alcohols, it can provide a more efficient combustion formation.

In this study, the effects of the addition of a chemical, which is frequently preferred in the industry, to diesel fuel together with waste frying oil for the direct use of waste frying oils, on exhaust emissions.

2. Material Method

2.1 Fuel Mixtures

Diesel fuels were obtained from a local commercial company. Di ethylene butyl glycol ether chemical has a purity level of over 99.6%. This fuel was obtained from a company that sells chemical products. All fuels are supplied at once to avoid differences.

Experimental fuels were prepared volumetrically. For this purpose, new fuels were derived by adding 10% waste cooking oil and di ethylene glycol butyl ether at 5%, 10% and 20% by volume into diesel fuel. The volumetric mixtures and abbreviations of the test fuels are given in Table 1.

Table 1. Test fuels and mixing ratios

	Diesel Fuel	Waste Frying Oil	Di Ethylene Butyl Glycol Ether
D	100	0	0
DAĞ	90	10	0
DAĞD5	85	10	5
DAĞD10	80	10	10
DAĞD20	70	10	20

Some physical and chemical properties of the obtained mixtures were analyzed, and the results are given in Table 2.

Table 2. Physical and chemical properties of test fuels

	Viscosity (mm^2/s)	Density (g/cm^3)	Lower Heat Value (MJ/kg)	Flash Point (^{C})
Waste Oil	8.96	936	37.45	89
D	3.13	859	42.1	65
DAĞ	6.19	889	41.3	79
DAĞD5	5.11	875	41.5	71
DAĞD10	4.67	869	41.8	70
DAĞD20	3.86	861	41.9	63

2.2 The experimental setup

Experiments on the engine were carried out in an existing laboratory at Muş Alparslan University. You can measure fuel consumption, exhaust gas temperature, and exhaust gas values in engine test equipment. A schematic of the test setup is shown in Figure 1. Table 3 shows the technical specifications of the motor used in the experiment. Emissions measurements were performed using a Capelec CAP3201 exhaust system. Table 4 shows the technical specifications of the exhaust system. Exhaust gas temperature was measured using a K-type thermocouple. Fuel consumption was determined by mass using a precision balance.

Table 3. Technical specifications of the test engine

Engine	Model	186FAG
	Type	Air Cooled-Four Stroke
	Cylinder Displacement	418 cm^3
	Maximum Output Power	7 kW

Table 4. Technical specifications of exhaust emission device

Brand and Model	Capelec CAP 3201-4 GAZ
Operating Temperature	-10 ^{0}C file 55 ^{0}C
Humidity	%30-%90
HC (sensitivity 1 ppm)	0-20000 ppm Hexan
CO (sensitivity 0.001%)	0-5 %vol.
CO_2 (sensitivity 0.1%)	0-20 %vol.
O_2 (sensitivity 0.01 %)	0-21,7 %vol.
NOx (sensitivity 1 ppm)	30-10000 ppm
Oil Temperature	5 ^{0}C-150 ^{0}C
Lambda (air/fuel ratio)	0,8-1,2
Opacity (sensitivity %0.01)	0-9,99 m^{-1} (%)

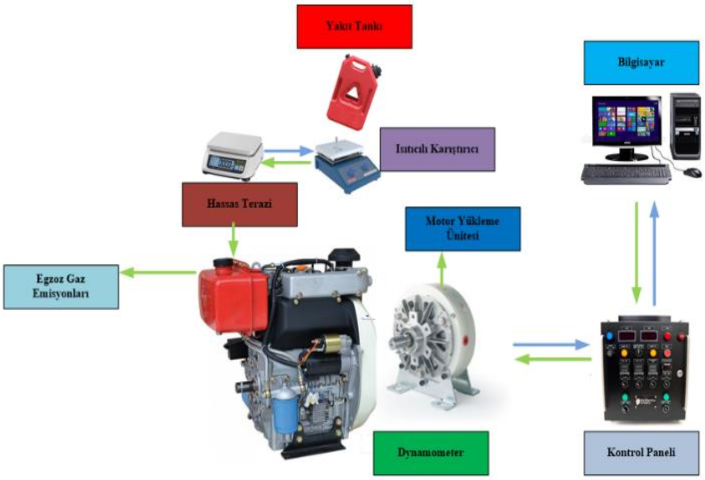

Fig. 1. Schematic picture of the experimental setup

The engine tests were repeated for all fuel mixtures at a constant engine speed of 3000 rpm and loaded at 20%, 40%, 60% and 80% of the engine's maximum load. Fuel consumption, exhaust gas temperature and exhaust emissions were recorded during all experiments.

3. Results and Discussion

Figure 2 shows the effect on Brake Specific Fuel Consumption (BSFC) at various engine loads. The data obtained show that the specific fuel consumption decreases as the engine load increases. As the engine load increases, the amount of fuel converted to useful work decreases. At the same time, adding waste vegetable oil to diesel fuel increases the amount of BSFC. Waste vegetable oil has a low calorific value and is more viscous and denser, which can lead to poor combustion in the cylinder, and it was found that more fuel had to be burned to achieve the same performance. The addition of diethylene glycol butyl ether to waste vegetable oil diesel fuel blends has been observed to reduce the amount of BSFC at all engine loads. Diethylene glycol butyl ether is an excellent solvent, thus reducing the viscosity and density of used oil in fuel mixtures. In this case, the combustion is partially improved, resulting in better combustion of the fuel mixture. The highest fuel consumption value was measured with the DAG fuel mixture at 20% engine load at 1930 g/kWh, while the lowest fuel consumption value was measured at 1703 g/kWh with DAGD20 fuel. Based on all engine loads, the best BSFC value was found to be 273 g/kWh with the DAGD20 fuel blend.

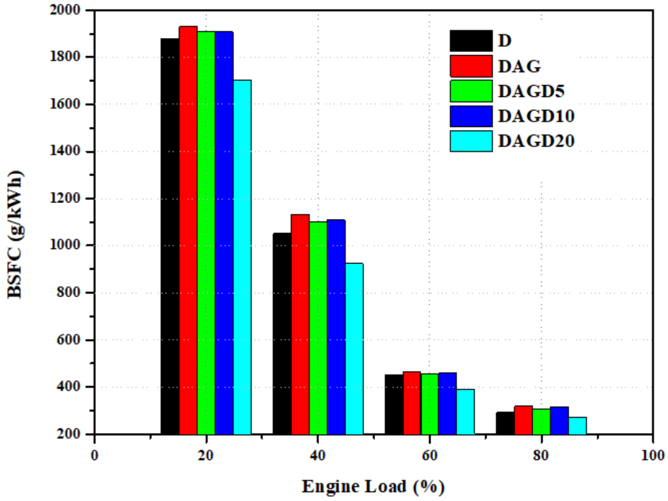

Fig. 2. BSFC change

In a diesel engine, the temperature inside the cylinder rises due to the mixture of the air-fuel mixture sucked into the cylinder. The temperature value in the cylinder also changes with combustion efficiency [17, 18]. In addition, prolonged combustion of the exhaust gas can lead to increased exhaust gas temperature values due to incomplete combustion of the fuel mixture in the cylinder. Figure 3 shows the evolution of exhaust gas temperature as a function of engine load. As engine load increases, exhaust gas temperature values increase for all fuel mixtures. As is known, the increase in engine load in diesel engines is regulated by the amount of fuel sucked into the cylinder. Therefore, it is considered that the exhaust temperature rises due to the increase in the amount of fuel in the cylinder. At all engine loads, the exhaust gas temperature decreases compared to the DAG fuel mixture and D fuel but increases with the DAGD20 fuel mixture. Volatile chemicals in the DAGD20 fuel mixture are believed to cause this increase, and exhaust gas temperature values increase with improved combustion efficiency. The maximum exhaust gas temperature is measured at 446 °C at 80% engine load using the DAGD20 fuel mixture and the minimum exhaust gas temperature is measured at 227 °C at 20% engine load using the DAG fuel mixture it was done.

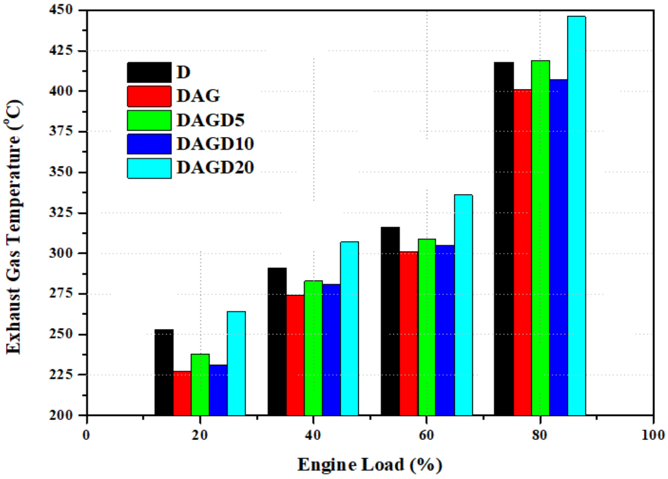

Fig. 3. Exhaust gas temperature change

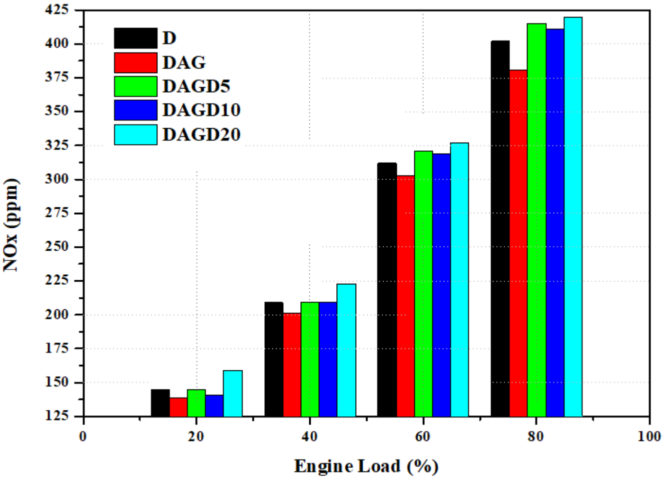

Fig. 4. NOx emissions change

Figure 4 shows the change in nitrogen oxides as a function of engine load. NOx emissions increase with all fuel blends as engine load increases. It is known that as engine load increases, more fuel flows into the cylinder. In this case, the combustion end temperature in the cylinder rises. NOx emissions, therefore, increase with increasing temperature. The DAG fuel blend reduced NOx emissions at all engine loads, while the DAGD20 fuel blend showed an increase. This situation parallels the exhaust gas temperature. As the exhaust gas temperature value increases, the NOx emissions also increase. Experiments have shown that the DAG fuel blend yielded the lowest NOx emissions at 139 ppm and the DAGD20 fuel blend yielded the highest NOx emissions at 420 ppm.

Figure 5 shows the evolution of CO emissions as a function of fuel mix and engine load. In a diesel engine, the amount of fuel delivered to the cylinder increases as the engine load increases. In this case, the combustion temperature will increase. This improves combustion performance and reduces CO emissions. Adding waste oil to diesel fuel increases the CO emissions at all engine loads, whereas adding diethylene glycol butyl ether to the fuel mixture reduces CO emissions. This situation can be explained by the increased viscosity, density, and calorific value of the fuel mixture. Lower viscosity and density and higher calorific value result in better, more efficient combustion and reduced CO emissions. The lowest CO emission value was measured at 0.29 ppm at 80% engine load using D fuel, while the highest CO emission value was measured at 1.11 ppm at 20% engine load and DAG fuel mixture rice field.

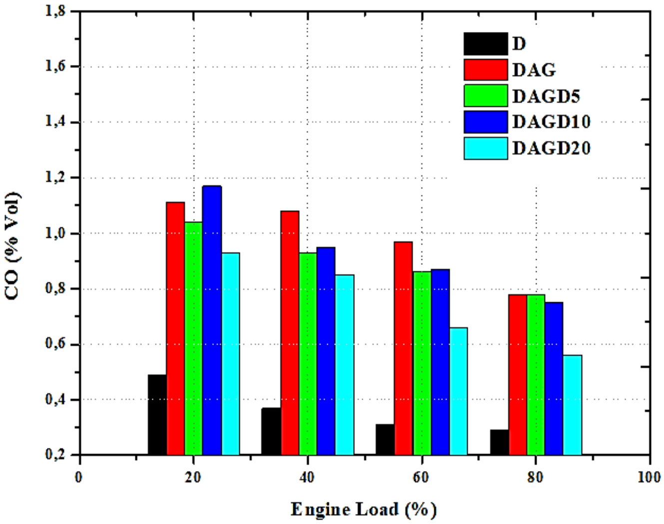

Fig. 5. CO emission change

Figure 6 shows the evolution of CO_2 emissions as a function of fuel mix and engine load. As engine load increases, CO_2 emissions increase with any fuel blend. As engine load increases, more fuel/air is drawn into the cylinder. This situation leads to an increase in total emissions. Adding waste oil to diesel fuel reduces CO_2 emissions at all engine loads. Some physical properties of the fuel are observed to change when the used oil is added. This situation could partially exacerbate combustion and, in this case, reduce CO_2 emissions. The addition of diethylene glycol butyl ether to diesel fuel and spent petroleum fuel mixtures partially increases CO_2 emissions. This situation can be explained by improving the physical properties of the fuel mixture and increasing the combustion efficiency of the chemicals used. In terms of CO_2 emissions, the lowest value measured at 20% engine load using the DAG fuel blend was 1.65, while the highest CO_2 emission value was 2.32 measured at 80% engine load using the D fuel blend was.

Figure 7 shows the evolution of HC emissions as a function of fuel mix and engine load. All fuel blends reduced HC emissions with increased engine load. The regularity of the post-combustion temperature and the post-combustion temperature regime improved the combustion efficiency, resulting in a decrease in HC emissions, despite the increased fuel mass as a function of engine load. Cylinder wall heating prevents the formation of quench zones that can occur during injection, so HC emissions tend to decrease with engine load. By adding used oil to diesel fuel, it can be observed that HC emissions increase as the viscosity and density values increase. Adding waste oil to diesel fuel increases its viscosity and density. As a result, the droplet diameter increased, and the injector spray method changed. Due to poor air-fuel mixture, combustion is partially impaired. In this case, it is assumed that the amount of HC emissions will increase. Some improvement in HC emissions is observed by adding diethylene glycol butyl ether to the diesel fuel/waste oil mixture compared to the waste oil mixture. The addition of diethylene glycol butyl ether reduced HC emissions due to the lower viscosity and density values of the fuel blend. In this study, the lowest HC value was 49 ppm for D fuel at 80% engine load, while the highest HC value was 277 ppm for DAGD5.

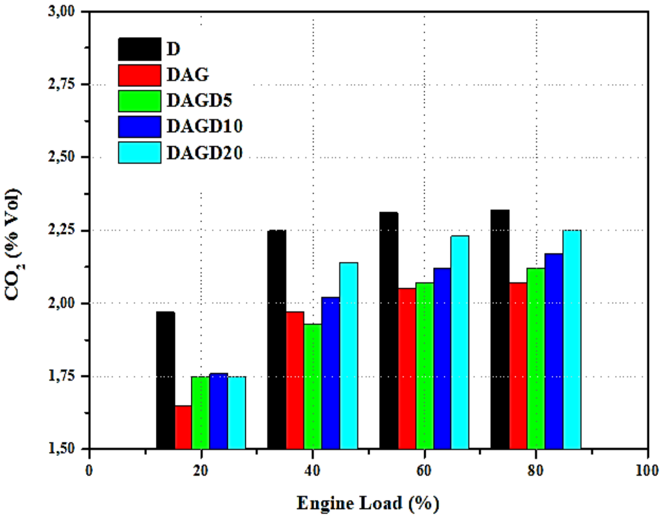

Fig. 6. Variation of CO_2 emissions.

Figure 8 shows the evolution of smoke emissions as a function of fuel mix and engine load. Smoke emissions of all mixed fuels decrease as engine load increases. An increase in engine load means an increase in end-of-combustion temperature. In this case, no partial cold zones are formed in the cylinder and combustion efficiency is continuously improved. Therefore, as engine load increases, soot emissions decrease. DAG fuel mixtures, made by adding used oil to diesel fuel, produce increased soot emissions at all engine loads. As is well known, adding waste oil to diesel fuel lowers the calorific value of the blended fuel while increasing viscosity and density values and lowering the flash point. Partial liberalization of combustion is thought to reduce the physical properties of mixed fuels and increase soot emissions. In addition, soot emissions were reduced by adding diethylene glycol butyl ether to the mixture of diesel fuel and waste oil. Looking at the soot emissions determined from the engine tests, the DAGD20 fuel mixture showed the lowest emission values of 2.4% at 80% engine load, while the DAG fuel mixture had the highest soot emission values at 20% engine load. showed.

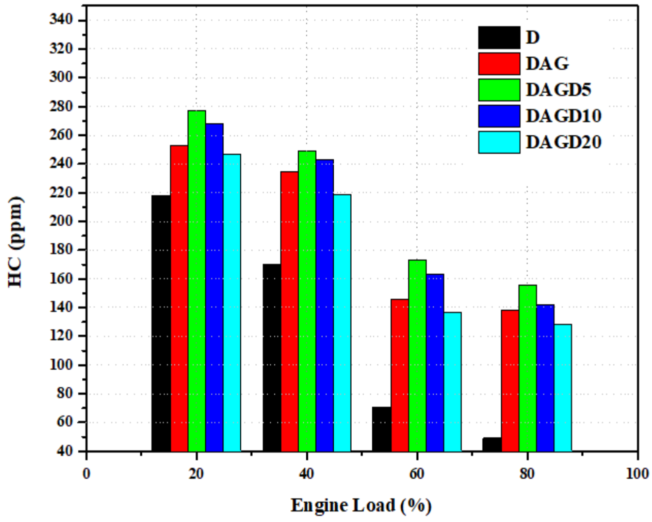

Fig. 7. Variation of HC emissions

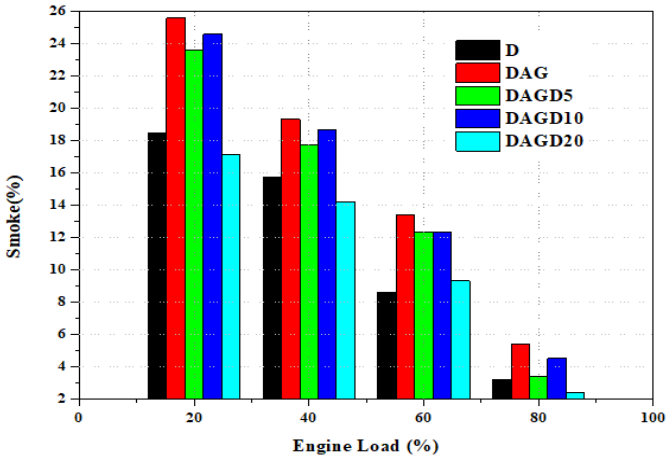

Fig. 8. Variation of Smoke Emissions.

4. Conclusions

This study aims to use waste vegetable oils directly in diesel engines. The waste frying oils provided for this purpose have been filtered and dewatered. Afterwards, diethylene is added to the diesel fuel. New fuel mixtures were obtained by mixing glycol with the addition of butyl ether. The main results and recommendations are given below.

- The initial viscosity value of waste vegetable oils, whose chemical and physical properties were tested, was measured as 8.69 mm2/s. The viscosity value of blending waste oils with diesel fuel was only reduced to 6.19 mm2/s. However, with the added chemical fuel additive, the viscosity value was corrected to 5.11 mm2/s with 5% diethylene glycol butyl ether, 4.67 mm2/s with the addition of 10% diethylene glycol butyl ether, and 3.86 mm2/s with the addition of 20% diethylene glycol butyl ether. The viscosity value in the final mixture obtained is at acceptable standards for diesel fuels at this stage.

- The initial density value of waste vegetable oils, whose chemical and physical properties were tested, was measured as 936 mm2/s. The density value of blending waste oils with diesel fuel was only reduced to 889 g/cm3. However, with diethylene glycol butyl ether added to fuel mixtures at 5%, 10% and 20% by volume, it is improved up to 875 mm2/s, 869 mm2/s and 861 mm2/s. The density value is within the limits accepted for the fuels of diesel engines.

- The heating value of diesel fuel is 42.1 MJ/kg, and the heating value of waste vegetable oil is 37.45 MJ/kg. While the heating value decreased to 41.3 MJ/kg with the waste oil added to the diesel fuel, the heating value was 41.5 MJ/kg, 41.8 MJ/kg, and 41.9 MJ/kg with the added 5%, 10% and 20% diethylene glycol butyl ether. up to its values.

- With the addition of waste vegetable oil and diethylene glycol butyl ether to diesel fuel, changes in fuel consumption values were observed. While the highest fuel consumption value was measured as 1930 g/kWh with DAG fuel mixture at 20% engine load, the lowest fuel consumption value was measured as 1703 g/kWh using DAGD20 fuel. Based on all engine loads, the best BSFC value was determined to be 273 g/kWh with a DAGD20 fuel mixture.

- At all engine loads, the exhaust gas temperature decreases compared to the DAG fuel mixture and D fuel, while it increases in the DAGD20 fuel mixture. It is thought that the volatile chemicals in the DAGD20 fuel mixture cause this increase and the exhaust gas temperature value increases with the increase in combustion efficiency. While the highest exhaust gas temperature was obtained with the DAGD20 fuel mixture at 446 C at 80% engine load, the lowest exhaust gas temperature was recorded as 227 C at 20% engine load with the DAG fuel mixture.

- While there was a decrease in NOx emissions with the DAG fuel mixture at all engine loads, there was an increase with the DAGD20 fuel mixture. This situation shows parallelism with the exhaust gas temperatures. Increasing exhaust gas temperature value also increases NOx emissions. In the experiments, the lowest NOx emission was obtained at 139 ppm in the DAG fuel mixture, while the highest NOx emission was obtained at 420 ppm in the DAGD20 fuel mixture.

- The lowest CO emission value was measured with 0.29 ppm at 80% engine load with D fuel, while the highest CO emission value was measured with 1.11 ppm at 20% engine load using DAG fuel mixture.

- In terms of CO2 emissions, the lowest value was measured at 1.65 with the use of DAG fuel mixture at 20% engine load, while the highest CO2 emission value was measured with the use of D fuel mixture at 2.32 at 80% engine load.
- In the study, the lowest HC value was measured as 49 ppm with D fuel at 80% engine load, while the highest HC value was measured as DAGD5 with 277 ppm.
- When the soot emissions obtained from the engine tests are examined, the lowest emission value was obtained with the figure of 2.4% at 80% engine load when using the DAGD20 fuel mixture, while the highest soot emission value was measured with the DAG fuel mixture at a rate of 25.6% at 20% engine load.
- The study should be repeated on large engines and vehicles and its effects on different engine types should also be investigated.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest in the study.

CRediT Author Statement

Salih Özer: Conceptualization, Supervision, Conceptualization, Writing-original draft, Validation, Data curation, Formal analysis **Cem Cenab Özen:** Writing-original draft, Data curation, Formal

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