Original Research Article

The Effects of Camelina Ethyl Ester on the Performance of Diesel Engine and Combustion Characteristics

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Abstract

Due to the shortage of the conventional fossil fuels and air pollution from combustion, new, sustainable and cleaner fuel resources are urgently required. Biodiesel has been introduced as a potential and alternative fuel for years. Biodiesel can be produced from different sources such as vegetable oils, animal fat, waste oil, etc. This study is intended to determine the effects of camelina ethyl ester, which is obtained from raw camelina oil by using ethanol, on engine performance mixing it with diesel fuel proportionately. Diesel, 80% diesel and 20% camelina ethyl ester by volumetrically and 100% camelina ethyl ester fuels were used as fuel. In the experiments, a four-cylinder, 1900cc, with turbocharged supplier diesel engine with Common - Rail fuel injection system was used. The experiments were repeated 3 times and the averages of the results were taken. When the results were investigated, it was seen that maximum torque, maximum power and specific fuel consumption values were measured in diesel fuel. Power and torque values of B20 and B100 fuels were a little lower than in diesel fuel and their specific fuel consumption was higher than the others.

Key Words: Ethyl Ester, Camelina bio-diesel, Engine Performance, Combustion Characteristics

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1. Introduction

Energy is one of the most important items necessary to meet the basic needs of human life. Per capita consumption of energy is one of the development signs in a country. Energy need is increasing every passing day and energy gap occurs due to the fact that the world population and industrialization are also gradually increasing [1-3].

Striking progress has been made in internal combustion engines in which petroleum gasoline diesel are generally used as an energy source since they were invented and they have an important position in industry and in our daily lives. Internal combustion engines have been started to be used in large parts of sea, land and air transport [4-6]. Despite this potential, both problems, occurred in energy sources and environmental threats as a result of the use of these sources especially in recent years have caused new searches for the use of the sources and a search for alternative sources has become a current issue [7-10].

The studies performed on this issue in recent years show that biodiesel energy has come into importance among energy sources. Biodiesel is an alternative diesel fuel obtained from edible sources such as animal or vegetable oil [11]. It can be chemically defined as mono-alkyl esters of long chain fatty acids. The interest for biodiesel has increased owing to the fact that it has advantages such as developing lubrication in the engine, having more positive exhaust emissions, biologically resoluble and edible. Biodiesel can be directly used in most of the diesel engines today and also it can be blend with diesel fuel [12-16].

Although there are many techniques to produce biodiesel, it is seen that transesterification method is generally preferred because of its low cost [17]. In biodiesel production, ethanol or methanol are used as alcohol [18-22]. When the studies performed so far are investigated, it is seen that methanol is used quite a lot in biodiesel production [9, 12, 15, 18, 22, 23].

Combustion and emission characteristics of diesel engine operated using biodiesel and its blends were also investigated by many experts and authors. Godiganur et al. [24] studied the effect of blend ratio of mahua oil in biodiesel on engine's performance and emission. They found that the higher mahua oil ratio in the blend, the lower HC and CO emissions, higher brake specific fuel consumption (BSFC) and higher NOx emission. Similar results were reported by Rao et al. [25] when they used rice bran oil biodiesel. In addition, the authors found that soot was reduced when the engine operated with biodiesel. Other researchers [26–28] also reported that using biodiesel as engine fuel will lead to higher BSFC and NOx emission comparing to using fossil diesel fuel. Baiju et al. [29] compared the performance and emission characteristics of a diesel engine fueled with methyl and ethyl esters produced from Karanja oil and PBDF as baseline fuel. Engine tests were conducted in a single-cylinder, four-stroke, naturally aspirated diesel engine at constant engine speed of 1500 rpm. The engine load was increased from 0% to 100% with 20% increments. According to their results, the brake thermal efficiencies of PBDF were higher than those of ester fuels at all loads. PBDF emitted higher oxides of nitrogen emissions than ester fuels. The BSFC of methyl ester was higher compared with ethyl ester. Methyl ester produced slightly higher power and better emissions than ethyl ester. Lapuerta et al. [30] produced methyl and ethyl ester fuels from waste frying oils and performed engine tests in a four-cylinder, four-stroke, turbocharged-intercooled, DI diesel engine. Although waste frying oils had similar properties, the feedstocks used in the methanolysis and ethanolysis reactions were different. As compared to PBDF, they found that pure methyl and ethyl ester fuels caused to slight increase in fuel consumption, slight differences in the NOx emissions and sharp reductions in the total hydrocarbon (THC), smoke opacity and particle emissions. However, volatile organic fraction of the particulate matter increased with ester fuels. Ethyl ester emitted lower NOx and THC emissions than methyl ester.

In this study, biodiesel was obtained from raw camelina oil using ethanol by means of transesterification method. Especially, the effect of camelina biodiesel with B20 (volumetrically 80% diesel and 20% camelina biodiesel) and B100 (100% camelina biodiesel) blend ratio, which is the European Union Target 2020, on engine performance for diesel fuel (D) was studied [5]. On the other hand, calculation of combustion characteristics of the engine depending on pressure and crank angle in cylinder was performed.

2. Material and Method

In this study, diesel fuel and camelina biodiesel were used as materials. The characteristics of raw camelina oil and diesel fuel are given in Table 1 [12]. Camelina seeds obtained post-harvest were hot-pressed at 85 0C and raw oil was obtained. The obtained raw oil was filtered and camelina biodiesel was obtained by means of transesterification method using ethanol as alcohol and sodium hydroxide (NaOH) as a catalyser. A sample of 1000 ml of oil was taken in a container and heated to 75 °C using heating coil at a minimum stirring speed. A fixed amount of ethanol and NaOH were vigorously shaken in a conical flask and poured into the container. The container was closed with an air tight lid. The mixture was then stirred for an hour and the solution was transferred to a separatory funnel and allowed to settle overnight. The biodiesel process turned the oil into esters, separating out the glycerol. The glycerol sank at the bottom and the bio-diesel floated on top and could be syphoned off. The crude ester phase was separated and the glycerol phase in it was washed by warm de-ionized water several times until the washed water became clear. The excess water in the ester phase was removed by evaporation under atmospheric condition.

Fuel properties of ester fuels were measured in Marmara Research Center-The Scientific and Technological Research Council of Turkey (MRC-TUBITAK), as seen in Table 2.

The engine used in the experiment is a 1.9 multijet diesel engine (Table 2). The tests were performed in hydraulic engine dynamometer. Its characteristics are given in Table 3.

For engine torque, specific fuel consumption, the tests of power; and to measure pressure in cylinder engine carried out simultaneously; AVL pressure sensor was used. Characteristics of in-cylinder pressure sensor are given in Table 4.

Table 1. Comparing Raw Camelina oil and diesel fuel characteristics

Characteristics	Raw Camelina Oil	Diesel
Density 15 °C (kg/m^3)	918	838
kinematic viscosity 40 °C mm^2/s	24	2.92
Flash Point °C	>220	102
lower heating value (MJ/kg)	38	42.3
Cinder (% kütle)	0.0025	0.01
Sulphur (mg/kg)	13.85	9
Water Content (mg/kg)	710	43.8
Acid Value (mg KOH/g)	1.39	-
Iodine number g.I$_2$/100 g)	151.5	-

Table 2. Some fuel properties

Biodiesel blends	Density (15 °C) (kg/m^3)	Flash point (ºC)	Kinematic viscosity (40 ºC) mm^2/s	Heating value (MJ/kg)
B0	828.75	> 63	2.96	42.70
B20	843.7	172	3.018	37.32
B100	884.6	201	5.18	36.68

Table 3. Technical characteristics of hydraulic dynamometer used in the study

Brake Type	BT-190 FR
Maximum braking power	100 kW
Maximum cyclic	6000 d/d
Maximum torque	750 Nm
Operating pressure of brake water	0-2 kg/cm^2
Water need for maximum power	2.3 m^3/sa
Maximum exit temperature of brake water	80 ºC
Torque measurement	Electronic load-cell
Direction of rotation	Right and left rotation

Table 4. AVL Characteristics of in-cylinder pressure sensor

| Specifications		Range	
Measuring range		0….250 bar	
Overload		300 bar	
Lifetime	≥	10^8	Load cycles
Sensitivity		16 pC/bar	Nominal
Linearity	≤	± 0.3%	FSO
Natural frequency	~	115 kHz	
Acceleration sensitivity	≤	0.001 bar/g	Axial
Shock resistance	≥	2000 g	
Insulation resistance	≥	10^{13} Ω	at 20 ºC
Capacitance		7 pF	
Operating temperature range	≤	400 ºC	
Thermal sensitivity change	≤	2 %	200…400 ºC
	≤	± 0.5 %	250±100 ºC
Load change drift		1 mbar/ms	Max. gradient
Cyclic temperature drift*	≤	± 0.5 bar	
Mounting bore		∅ 4.3 mm	Front sealed
Cable connection		M3x0.35	Negative
Weight		4.7 grams	Without cable
Mounting torque		1.5 Nm	

*at 7 bar IMEP and 1300 rpm, diesel
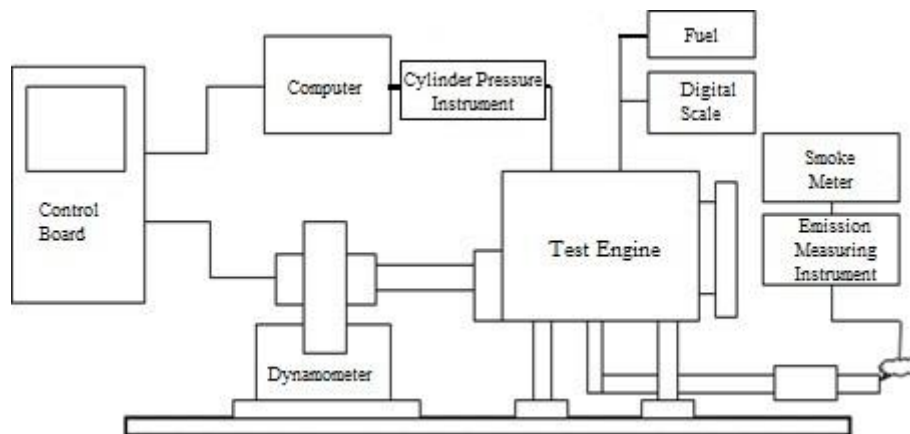
Figure 1. Experimental setup used in the study

General view of experimental setup is given in Figure 1. Tests were performed gradually starting from 1000 rpm to 4000 rpm at 500 rpm intervals. Engine torque, engine power and specific fuel consumption values were measured at each interval.

3. Results and Discussion

Engine torque changes of D, B20 fuel mixture and B100 fuels are given in Figure 2

depending upon engine rpm number.

As seen in the graphic, maximum engine torque is measured between 1750-2250 rpm in all types of fuels. When torque values were investigated, it was seen that the highest torque value was reached in diesel fuel. Whereas 167.68 Nm was obtained using diesel fuel in 2000 rpm where maximum torque was obtained, use of B20 fuel blend 157.84 Nm and use of B100 fuel measured 141.13 Nm torque at the same rpm. The fact that engine torque values of B20 and B100 fuel blends decrease in comparison with diesel fuel may be because lower heating value of camelina biodiesel is lower than in diesel fuel or intended atomization can't be provided because high viscosity makes it hard for the fuel to be injected.

Depending on engine speed, the changes of engine power values of diesel fuel, B20 fuel mixture and B100 fuel are given in Figure 3. It is seen in this graphic that engine power values reach maximum value between 2750-3250 rpm.
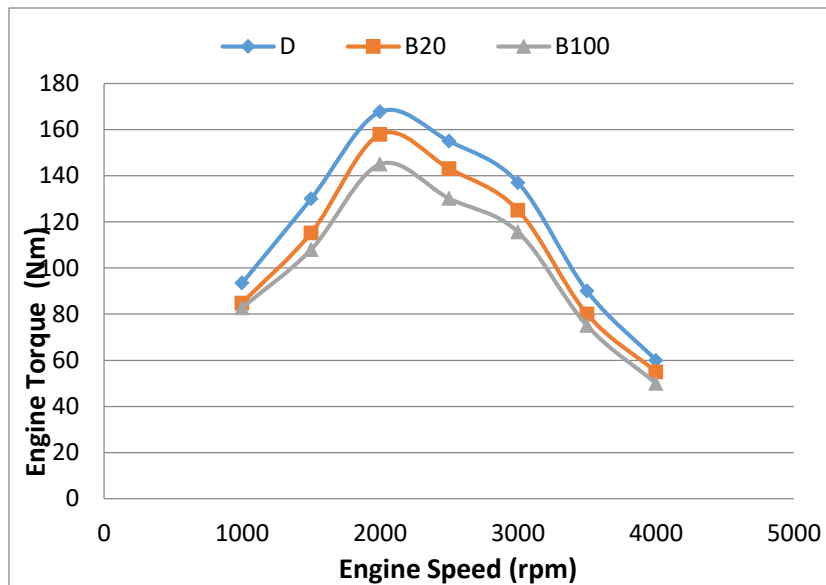

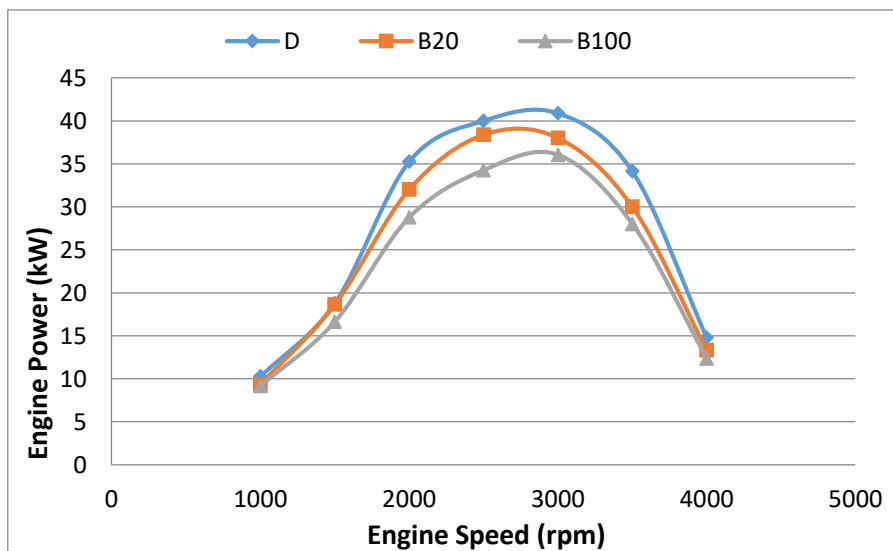**Figure 2.** The changes of engine torque values

Figure 3. Engine power values

Maximum engine power of diesel fuel was measured as 40.92 kW at 3000 rpm, B100 fuel generated 36.25 kW and B20 fuel mixture generated 38.37 kW at the same engine speed. It was determined that the difference between engine power values of other fuels and of diesel fuels got bigger after 3000 rpm. Low engine power in using biodiesel fuels may result from the fact that lower heating value of camelina biodiesel is

lower than in diesel fuel and its viscosity and density are high. High viscosity and density cause fuels not to be injected from the injectors as required. This situation extends ignition delay which affects combustion and causes a deterioration of combustion.

Depending on engine speed, the changes of specific fuel consumption values of diesel fuel, B20 and B100 fuels are given in Figure 4.
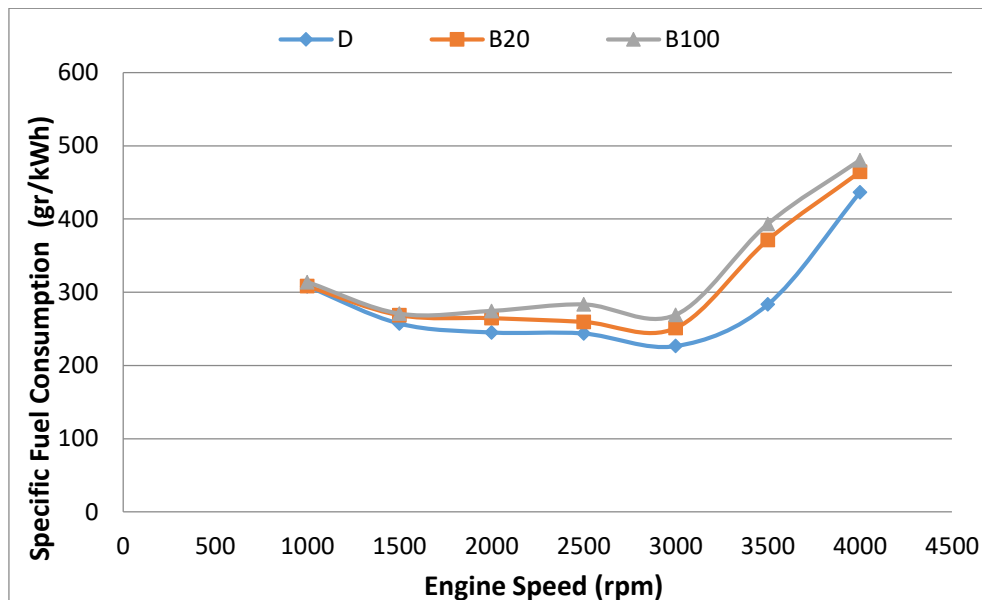

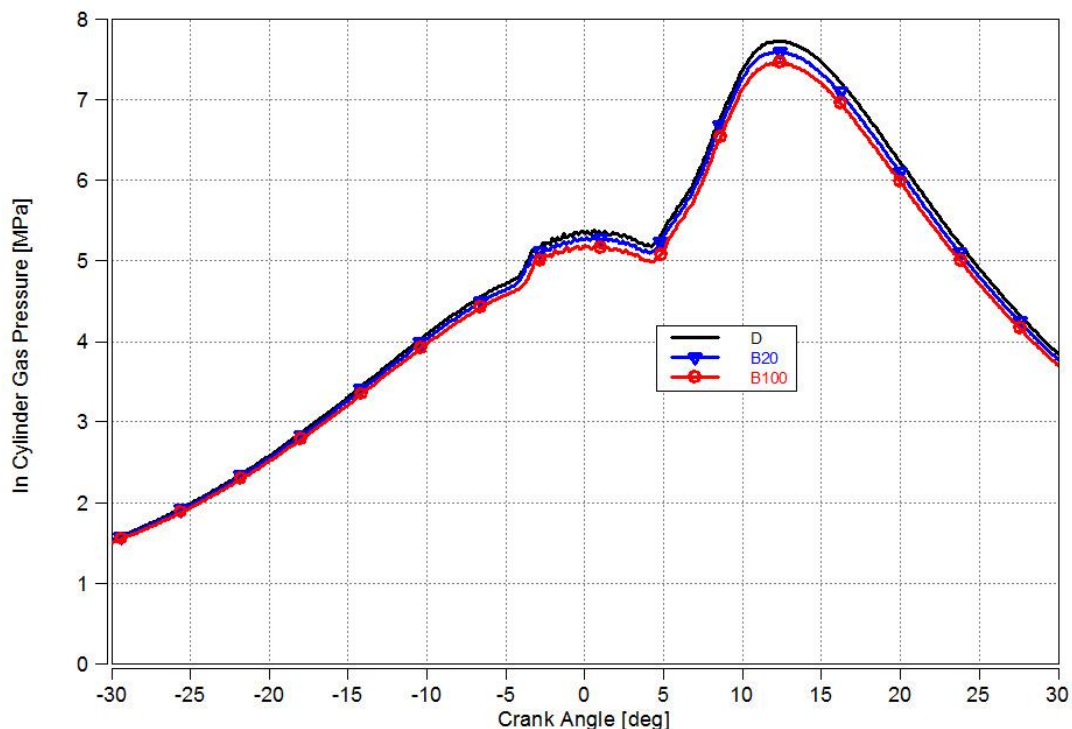**Figure 4.** The changes of specific fuel consumption values

Figure 5. In-cylinder gas pressure values

It was seen that the lowest specific fuel consumption value was 220.32 g/kWh in diesel fuel at 3000 rpm. It was detected that specific fuel consumption value of B20 fuel mixture was 240.18 g/kWh and of B100 fuel was 270.14 g/kWh at the same rpm. Specific fuel consumption values of biodiesel fuels were found to be higher than in diesel fuel. This may result from the fact that biodiesel fuels consume more amount of fuel to generate the same power since they have lower heating value than diesel fuel has.

100

When the obtained engine power, torque and specific fuel consumption values were investigated, some similarities were observed with biodiesel mixtures made so far and with performance values carried out by using different biodiesel raw materials [31-36].

Gas pressure in cylinder was studied as combustion characteristics. In an internal combustion engine, the distribution of mechanical load in terms of crank angle occurring in cylinder as a result of combustion of a fuel is expressed with cylinder gas pressure curves [17]. In-cylinder gas pressures of test engine were measured at 2000 revolutions per minute (rpm) where maximum torque value was obtained and which is mostly used in cycle. The changes of cylinder gas pressure values belonging to different rpms in terms of crank angles are given in Figure 5.

In the measurement of in-cylinder gas pressure, pressure values were recorded every 0,1 angle of crank crankshaft during 120 cycles and their averages were taken. When the figure was investigated, it was seen that in-cylinder gas pressures were quite similar to each other in all types of fuels at 2000 rpm. The highest in-cylinder gas pressure value obtained in working regime where the engine used diesel fuel was 7.8 MPa, the highest in-cylinder gas pressure value obtained in working regime where the engine used B20 was 7.6 MPa and the highest in-cylinder gas pressure value obtained in working regime where the engine used B100 was 7.4 MPa.

When the results were investigated, in-cylinder gas pressure value reduced even if just a bit depending upon the increase of biodiesel ratio in fuel mixture. This may result from the fact that lower heating value of biodiesel is lower than diesel fuel and its energy released during combustion is also lower.

4. Conclusion

In this study, combustion characteristics were investigated in terms of performance, emission and in-cylinder gas pressure value in various rpms in a 4-cylinder, water-cooled, four stroke, turbocharged, intercooler, common rail fuel system diesel engine. B20, B100 and diesel fuel were used a fuels. The obtained results were compared to diesel fuels. The highest torque and engine power values were reached in diesel fuel. The lowest specific fuel consumption values were reached in diesel fuel. The main reason of high specific fuel consumption is biodiesel fuels have a lower heating values and engines consume more fuels to generate the same power.

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