Available online at www.academicpaper.org
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ISSN 2146-9067
International Journal of Automotive Engineering and Technologies
Vol. 5, Issue 3, pp. 102 –114, 2016

International Journal of Automotive Engineering and Technologies
http://www.academicpaper.org/index.php/IJAET

Original Research Article

The Effects of Apricots Seed Oil Biodiesel with Some Additives on Performance and Emissions of a Diesel Engine

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Received 25 March 2016 Accepted 11 November 2016

Abstract

The purpose of this experimental work is to investigate influences of using manganese (Mn) as a combustion catalysts on apricot seed oil based biodiesel production and its engine out parameters. The metal based additive (Mn) was added to biodiesel (B50) at different dosages of 20-40-60 μmol/L. Also, other additives the propylene glycol and dodecanol were added into apricot seed oil biodiesel (B50) at rates of 5% and 1%, respectively for preparing test fuels.This additives improved flash point, pour point and viscosity of the biodiesel (B50) fuel. Experiments were carried out to clarify the effects of all additives added to biodiesel on performance and emission characteristics of a three-cylinder DI diesel engine operated at a constant speed of 1500 rpm and different loads from 2,50 to 10 kW. The engine test results revealed that specific fuel consumption, NO_x were not changed significantly with the adding additives to biodiesel (B50) fuel, while CO, HC and smoke emission profiles were improved.

Key Words:Apricot seed, Methyl ester, Manganese (Mn), additive, Diesel engine

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1. Introduction

Exploration of non-conventional energy sources are continuously expanding owing to the increasing demands in the use of petroleum products, rising petroleum prices, the energy crisis, global climate changes and the increasing threat to the environment from exhaust emissions [1,2]. One of these most important alternative sources is biodiesel fuel.

There have been many researches on fuel production and fuel additives. A renewable fuel is biodiesel, which can be domestically produced from vegetable oil and animal fats. The oil or fat is reacted with alcohol in order to form esters. The reaction requires strong catalysts such as alkaline or acid. These esters are known as biodiesel fuels. Biodiesel can be used on its own, or mixed with petroleum diesel fuel in any unmodified diesel engine.

Biodiesel is an oxygenated, sulfur and aromatic hydrocarbons-free, biodegradable, non-toxic, and environmentally friendly alternative diesel fuel. Biodiesel hydrocarbon chains are generally 16–20 carbons in length and contain oxygen at one end. Biodiesel contains about 10–12% oxygen by weight [3,4].

In addition, Cetane numbers of biodiesels range between 49 and 62. These fuel properties improve combustion efficiency and emission profile in a diesel engine. Previous studies showed that biodiesel and blends of biodiesel with diesel fuel reduce particulate material, hydrocarbon, carbon monoxide and sulphur oxides [5]. However, generally nitrogen oxides emissions are slightly increased depending on biodiesel concentration in the fuel [6].

Catalysts are very important in order to start esterification reaction. Although, alkali-catalyzed transesterification is much faster than acid catalysts, it is not suitable for esterification of free fatty acids. Because, alkaline catalysts are very sensitive to free fatty acids. During the reaction, free fatty acids may react with an alkali catalyst to form soap and water, which diminishes the ester yield [7,8]. Therefore, acid catalysts such as H_2SO_4 or HCl are preferred for esterification of free fatty acids. In addition, acid-catalyzed esterification reaction of free fatty acids is relatively faster than acid-catalyzed transesterification reaction of triglycerides [9]. Altıparmak et al. reported that tall oil fatty acid methyl ester was synthesized with H_2SO_4 catalyst and effects on diesel engine performance and emissions were investigated [10].

Acid-catalyzed transesterification reaction follows that:

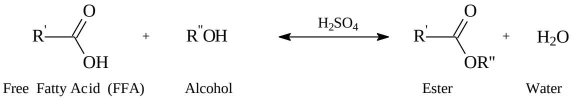


Figure 1. Acid-catalyzed transesterification reaction.

Many vegetable oils such as sunflower oil [11] , olive oil [12] , soybean oil [13], cotton oil [14] , hazelnut oil [8], rubber seed oil [15] , cooking oil [6], polanga seed oil [16] and karanja oil [17] etc. have been used for producing biodiesel fuel. Also, distilled tall oil esterified with alcohol was tested in a direct injection diesel engine at full load condition [18].

Reduction of NO can be attained while using biodiesel can be achieved by improving the diesel engine design and combustion chamber. But the reduction rates achieved have not been adequate to meet the emission standards. Further reduction in emission and improvement in engine efficiency can be achieved by use of fuel additives. Metal based additives have been employed as combustion catalyst to promote the combustion and to reduce fuel consumption and emissions for hydrocarbon fuels.

These metal based additives include cerium (Ce), cerium–iron (Ce–Fe), platinum (Pt), platinum–cerium (Pt–Ce), iron (Fe), manganese (Mn), barium, calcium, copper [19], palladium and titanium. The reduction of emission while using metal based additive may be either due to the fact that the metals react with water vapor to produce hydroxyl radicals or serve as an oxidation catalyst thereby reducing the oxidation temperature that results in increased particle burnout [20-23].

The aim of this study is to produce methyl ester from the apricot seed oil at optimized conditions and improve the fuel's properties with manganese additive, as a novel process. Diesel fuel and blend of apricot seed methyl ester doped manganese additive with diesel fuel (50%) were tested in a direct injection diesel engine at different load conditions. Additionally, in the scope of this study, dodecanol, propylene glycol additives were added to fuel B50 to improve the emission and engine performance values.

2. Materials and method

2.1. Test Fuel

Although biodiesel can be produced by every oil type that is used in households, obtaining the required quality and yield is related to the property of the oil. In order to obtain high quality biodiesel, the reaction type that is to be carried out must be determined first. It is based on significantly the free fatty acid (FFA) ratio of the oil that is to be used. Before, biodiesel production process was designed, the FFA ratio was specified in this study. The results of the chemical analysis in terms of stearic and oleic acid are shown in Table 1. Based on the analysis results, the most appropriate method is determined as two-step transesterification.

Table 1. Free fatty acid rates in terms of stearic and oleic acid.

Oil type	Stearic acid (%)	Oleic acid (%)
Apricot seed oil	6,80	6,76

Transesterification is the process of reacting a triglyceride with alcohol in the presence of a catalyst to produce glycerol and fatty acid esters. It is difficult to produce ester from apricot seed oil using an alkaline catalyst (NaOH) because of its high free fatty acid (FFA). Therefore, a two-step transesterification process was chosen to convert the apricot seed oil into its methyl ester. The first step acid, catalyzed esterification reduces the FFA value of the oil to about 5%. The second step, alkaline catalyzed transesterification process converts the products of the first step to its mono-esters and glycerol. In acid esterification, 2000 ml of apricot seed oil was heated to about 60°C, and then 400 ml methanol was added and stirred for a few minutes. 1.3% H_2SO_4 was also added into this mixture, and stirred at a constant rate at 60°C for 60 min. After the reaction was over, the solution was allowed to settle for 24 h. in a separating funnel. The excess alcohol along with sulphuric acid and impurities floated at the top surface and was removed. The lower layer was separated for further processing (alkaline esterification). In alkaline catalyzed esterification, the products of the first step were again heated to about 55 to 60°C. With this mixture, 5g of NaOH dissolved in 200 ml of methanol was added and stirred for 60 min. After the reaction was over, the solution was again allowed to settle for 24 h. The glycerin settled at the bottom and esterified apricot seed oil raised to the top. This esterified apricot seed oil was separated and purified with warm water. After washing, the final product was heated up to 60 °C for 10 min. The esterified apricot seed oil thus prepared and was referred to as methyl ester of apricot seed oil (B100). After the product taken its final form, it was filtered and stored. The physical and chemical properties of the obtained biodiesel are shown in Table 2.

Table 2. Physical and chemical properties of the test fuels.

Property	Diesel Fuel	ASOME
Viscosity (Mpa.s)	4,24	4,803
Density (Kg/ m^3)	831,96	872,7
Flash Point (°C)	65,50	151,4
Cetane Index	53,1	58,80
Pour Point (°C)	-14	-10,20
Clorific Value (Cal/gr)	9302	9148

The biodiesel that has been obtained as a result of chemical processes is mixed with diesel fuel by volumes of 20%, 35%, 50%, 75%, and 100% in volume to prepare the samples. Whereas for the samples that contain additives, 1 lt (50%) diesel fuel was mixed with 1lt (50%) biodiesel, and 20 ml (1%) dodecanol, 100 ml (5%) propylene glycol and different dosages of Mn (20–40–60 μmol/lt) were added. The goal to add additives to fuel samples is to obtain the optimal physical and chemical properties. Since there was no metal-based study with the produced apricots oil methyl ester, the study was carried out in a wide range.

2.2. Engine test apparatus and method

The experimental investigation were carried out on a three cylinder, four-stroke water cooled, naturally aspirated, direct injection diesel engine. A schematic representation of experimental set up is shown in Fig. 2. During the study, no modifications were done on the engine, generator or on any other component. The fuel samples were tested under the same conditions. The technical properties of the diesel engine are given in Table 3.Technical properties of the gas analyzing device are given in Table 4.

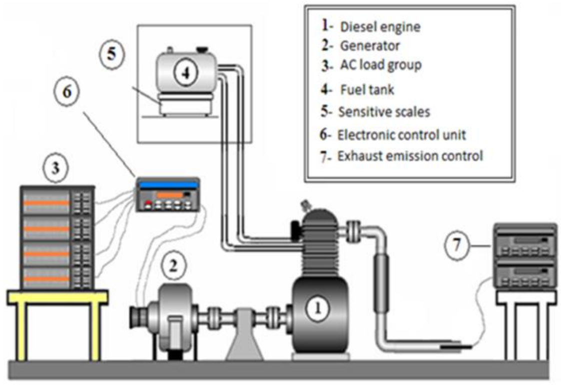


Figure 2. Schematic diagram of the engine test bed.

Table 3. Test engine specifications.

Item	INTER-IDE314NG
Spray system	Direct injection
Cooling system	Water-cooled with radiator
Number of cylinders	3
Bore x Stroke	80 x 90
Stroke volume (lt)	1,40
Compression ratio	18/1
Maximum power (kW/HP)	13,50 / 18

Table 4.Technical properties of the gas analyzing device.

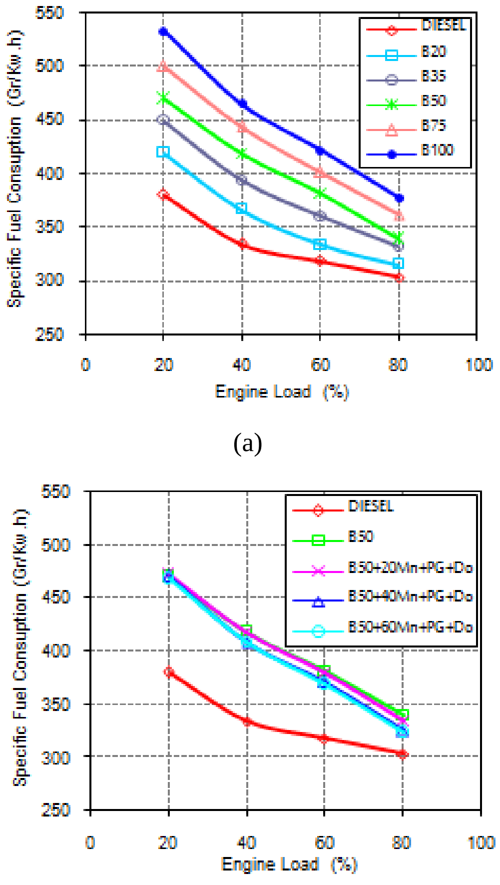
Components	Measurement Range	Precision
CO	0.00 – 15.00 % Vol.	0.001 % Vol.
CO_2	0.00 – 20.00 % Vol.	0.1 % Vol.
HC	0 – 20000 ppm Vol.	1 ppm Vol.
O_2	0.00 – 21.7 % Vol.	0.01 % Vol.
Lambda	0.500 – 9.999	0.001
NO	0 – 5000 ppm Vol.	1 ppm Vol.

In the experiments, a synchronous generator with the maximum active power of 12.50 kW was used to start the engine. The engine speed is kept constant at 1500 rpm. The engine load is variable. The engine worked with standard fuel without load for period of time, and when the engine reached the optimal temperature, 4 different load levels of 2.50 kW (20%) – 5 kW (40%) – 7.50 kW (60%) – 10 kW (80%) were applied on the engine. This procedure was repeated twice and the averages of the values were calculated. In the different loads, the specific fuel consumption (gr/kWh), thermal efficiency (%), HC (ppm), CO (%), NO_x (ppm), exhaust temperature (^oC) and smoke values were measured.

2.3 Engine performance and emissions with test fuels

The SFC value of biodiesel was compared with that of diesel. When biodiesel was compared with diesel, it was seen that there was an increase of 7.60% with B20 fuel, 15.20% with B35, 20.8% with B50, 28% for B75, and 35% with B100.The SFC values are shown in Figure 3 (a).

As seen in Figure 3(a), the lowest specific consumption was obtained when the diesel with the lowest value was used, and the highest specific consumption was obtained with B100. The SFC values of the fuels increase proportionally with increasing biodiesel amount in mixtures. This increase is thought to be related to the low thermal vale and the high viscosity and density of biodiesel. As seen on Figure 3(a), even though the biodiesel and diesel were tested under the same load, and produced the same power, the SFC of biodiesel as higher than that of diesel. This was thought to be due to three reasons. First, the amount of biodiesel sent off the injection pump increases due to higher density.



(a)

(b)

Figure 3. Variation of SFC at different engine loads for various fuels. (a) Biodiesel, (b) B50 with additives

In other words, it is inevitable to come up with a high SFC value for high density fuels. The second reason is the viscosity difference between the fuels. When high viscosity fuels are sent to the combustion chamber from the same injection nozzle, they end up having bigger particles. Another factor that affects the SFC is the thermal value of the fuel. As every sample was tested under the same loading conditions, the same energy is expected to be obtained at the end of combustion. In order to obtain the same amount of thermal energy, a larger amount of biodiesel needs to be sent to the combustion chamber. As a result, the density, viscosity and thermal values of the injected fuel affects the SFC [14].

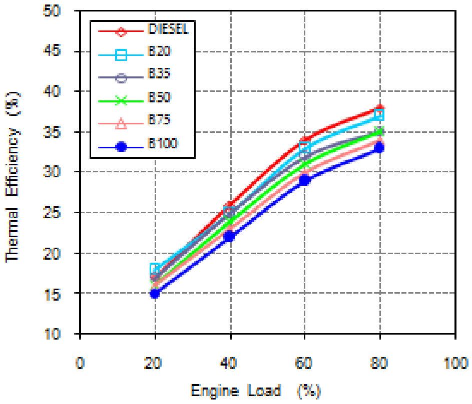
The SFC of B50 was compared to the SFC values of fuels with additives. When the SFC values of the fuels with additives were compared with B50 fuel, a decrease of 0.40% was observed in B50+20Mnµmol/lt+PG fuel, 2% decrease was seen in B50+40Mnµmol/lt+PG, and 2.30% decrease in B50+60Mnµmol/lt+PG was observed. The SFC values are shown in Figure 3 (b).
The effect of the additives on the declining SFC can be seen on Figure 3(b). It is thought that the additives improve the cetane number, viscosity, density and the flash point, and they also have a catalyzing role in combustion, which is thought to decrease the SFC value. In addition, when the Mn additive amount increased in B50, a further decline in SFC was observed, which can be seen in Figure 3(b). It was pointed out that adding metal based additives to fuel improves the cetane number, viscosity and flash point. However, it was also pointed out that there was an optimal amount of additives, and when this amount was exceeded, the cetane number, density, viscosity and flash point was negatively affected [4]. 20, 40, 60 µmol/lt of Mn was added to the B50 fuel, which was produced in Apricots Seed Oil Methyl Ester (ASOME). Figure 3(b) shows that the best performance was given in the 40 µmol/ltMn that was added. It was thought that higher oxygen content in chemical structure of additive, low carbon rate, low viscosity, high cetane number, low ignition temperature compared to diesel fuel had a positive effect on decreasing SFC.

Thermal efficiency is calculated via the following formula using the specific fuel consumption and lower heating value.

$$\eta = \frac{36}{b_e H_u} \times 100 \qquad (1)$$

Where η is thermal efficiency (%), b_e is specific fuel consumption (kg/kWh) and H_u is lower heating value (kj/kg).

In internally combustible engines, the heat energy produced as a result of the burning of fuel inside the burning chamber is transformed into mechanical energy. Effective efficiency gives information as to what portion of the heat energy was transformed into useful work. The thermal efficiency values for all fuels under all load conditions were calculated and given in Figure 4(a).



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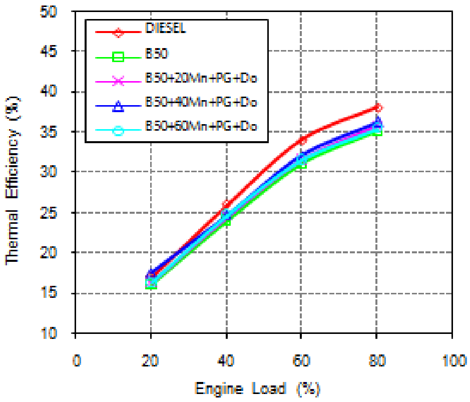


(b)

Figure 4. Variation of thermal efficiency at different loads for various fuels. (a) Biodiesel, (b) B50 with additives

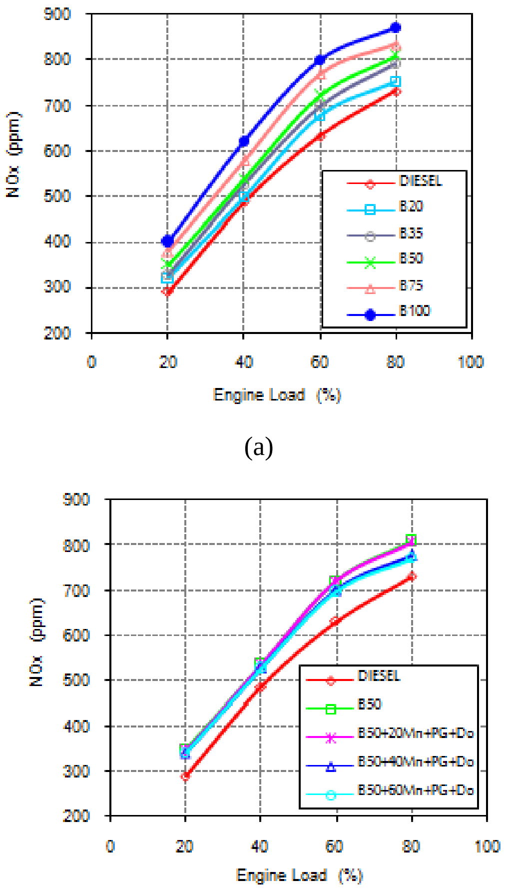
The thermal efficiency value of biodiesel was compared with that of diesel. When biodiesel was compared with diesel, it was seen that there was a decrease of 1.90% with B20 fuel, 4.94 % with B35, 7.88% with B50, 10.20% for B75, and 14.05% with B100.

It is observed in Figure 4(a) that the effective efficiency in biodiesel usage is lower in comparison with the ratio in diesel fuel usage. The highest efficiency was obtained with diesel fuel whereas the lowest efficiency was determined with B100 fuel. The low value of effective efficiency in the motor during biodiesel usage leads us to think that this is due to the high viscosity value of biodiesel fuel and its low heating value. Bad atomization and low heating value in biodiesel usage due to high viscosity resulted in a low brake effective efficiency in comparison with that of diesel fuel [24].

The thermal efficiency of B50 was compared to the thermal efficiency values of fuels with additives. When the thermal efficiency values of the fuels with additives were compared with B50 fuel, a increase of 0.83% was observed in B50+20Mnµmol/lt+PG fuel, 2.42% increase was seen in B50+40Mnµmol/lt+PG, and 2.51% increase in B50+60Mnµmol/lt+PG was observed. The effective efficiency values for all fuels under all load conditions were calculated and given in Figure 4(b).

It is seen in Figure 4(b) that the addition of additives to B50 fuel has increased effective efficiency. It is thought that the addition of additives to the fuel have positive contributions to properties such as cetane number, viscosity and flash point [24]. However, it has also been stated that there is an optimum value for the addition of metal based additives to the fuel and that the properties such as cetane number, density, viscosity and flash point will be affected negatively when this value is exceeded [24]. Mndo sings of 20, 40 and 60 µmol/lt have been made to B50 fuel prepared from ASOME. It is observed from Figure 4(b) that the best effective efficiency increase among the aforementioned scales is for Mn usage at 40 µmol/lt scale. It is thought that heating value and viscosity problems in biodiesel fuels may increase friction losses in the motor and also increase the effective efficiency in biodiesels due to the solution of heat transfer losses [25].

Nitrous oxides are released due to the engine working under high temperatures. NO_x term is the total amount of NO and NO_2 in the atmosphere. Diesel engines use up more air for combustion, compared to other engines. The NO_x emissions of biodiesels were compared with diesel. When biodiesel was compared to diesel in terms of NO_x, an increase of 5.10% was observed in B20, 9.35% increase was observed in B35, 12.80% increase was observed in B50, 19.60% increase was observed in B75 and 25.65% increase was observed in B100.



(a)

(b)

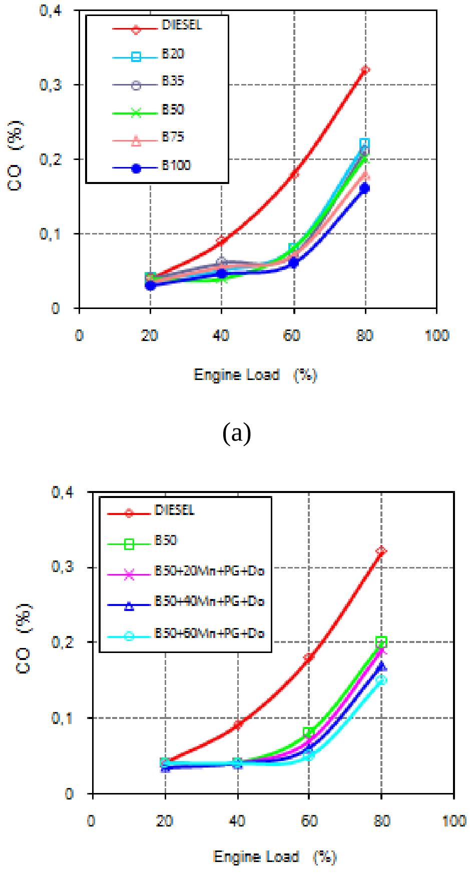
Figure 5. Variation of NO_x at different engine loads for various fuels. (a) Biodiesel, (b) B50 with additives

As seen in Figure 5(a), in low loads, the temperature of the internal cylinder is low, which causes low NO_x emission for all test fuels. With increasing load, an increase in NO_x fumes was observed. The increase in NO_x fumes is thought to be caused by the increase in the temperature of the inside of the cylinder. The exhaust temperature values in Figure 9(a) and the SFC values in Figure 4.2(a) support this. Increase in the temperature of the inside of the cylinder causes air motion, which enables NO_x emission [26]. However, with the increase of biodiesel in diesel fuel, the temperature increases, and this facilitates pressure and air motion. Another difference between NO_x emissions under the same load is thought to be due to the difference in thermal values. Biodiesel fuels require a greater mass for the same thermal load. Using more fuel in terms of mass might be the reason of increasing NO_x emissions.

The NO_x emissions of B50 fuel were compared to that of B50+20Mn+PG, B50+40Mn+PG and B50+60Mn+PG fuel. When the fuels are compared to the NO_x emission of B50, 0.10% decrease in B50+20Mn+PG fuel, 2.80% decrease was observed in B50+40Mn+PG, and a 3% decrease was observed in B50+60Mn+PG.

Since the additives contain oxygen and exhaust temperature increase, it is expected that NOx emissions increase. However, Figure 5(b) shows a decrease in NO_x emissions. It is thought that with the additives, the cetane number increase, the SFC values and flash point decease, which decreases NO_x emissions. Although the specific fuel consumption and the exhaust temperature is higher than diesel fuel, lower NO_x emissions were obtained. This is explained with higher cetane count and lower flash point, compared to diesel fuel. It was also emphasized that NO_x emissions decrease with increasing cetane count [27]. It is assumed that the additives prevent ignition lag and shortens the reaction time of nitrogen and oxygen. The fact that the combustion is shorter may be shown as the reason to the decrease in NO_x emissions. The higher viscosity and lower flash point of biodiesel fuel are causing an ignition lag which creates time for the reaction of nitrogen with [28].

The CO emissions of biodiesels were compared with diesel. When biodiesel was compared to diesel in terms of CO, a decrease of 38% was observed in B20, 39.50% decrease was observed in B35, 42.80% decrease was observed in B50, 46% decrease was observed in B75 and 53.50% decrease was observed in B100.The CO emissions for all fuels under all load conditions were calculated and given in Figure 6(a).



(a)

(b)

Figure 6. Variation of CO at different engine loads for various fuels. (a) Biodiesel, (b) B50 with additives

Figure 6(a) shows that the CO emission increases in parallel to increasing load. The increase in CO emission with increase in load was related to the increase in fuel consumption. Figure 6(a) also shows that the CO emissions of biodiesel are less than that of diesel fuel. The cetane count of biodiesel is high, and the chemical structure contains oxygen; these factors are thought to affect the decrease in CO emissions. Oxygen content in biodiesel contributes to better oxidation processes within the combustion chamber. This reduces CO emission and promotes higher NO_x emission. The advanced start of injection, caused by biodiesel usage, also contributes to a higher production of NO_x emissions [25]. At 20% load, the CO emissions of the test fuels were similar values, but when the load went up to 40%, 60% and 80%, significant differences in CO emissions could be observed, as seen in Figure 6(a). With the increase in biodiesel amount in diesel fuel, the cetane count and oxygen content increases, and this causes different amounts of CO emission. It is thought that with better properties for combustion performance will decrease CO emissions.

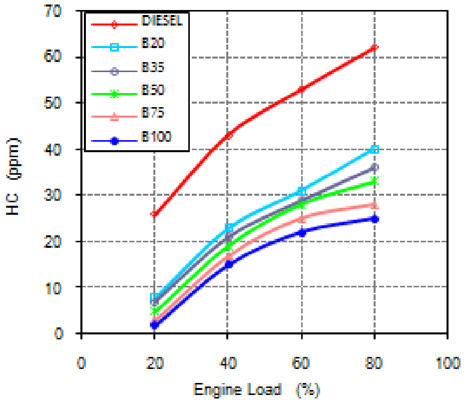
The CO emissions of B50 fuel were compared to that of B50+20Mn+PG, B50+40Mn+PG and B50+60Mn+PG fuel. When the fuels are compared to the CO emission of B50, 5% decrease in B50+20Mn+PG fuel, 14.90% decrease was observed in B50+40Mn+PG, and a 22% decrease was observed in B50+60Mn+PG. The CO emissions for all fuels under all load conditions were calculated and given in Figure 5(b).

The emission values of fuels with additives have lower CO emission than B50, as seen on Figure 6(b). The additives improve the cetane count, the flash point, viscosity and density, which improves the combustion yielding better results in comparison with those of B50 [29]. As seen in Figure 6(b), with increasing Mn content, the o emissions have decreased. Mn based additives improve the properties that affect combustion performance [25]. It is thought that improved combustion performance gives time for CO to convert to CO_2. The fact that the CO_2 emission of fuels with additives is higher than that of B50 supports this situation.

The most important factor in the production of HC emissions is the gases that remain from the previous cycle. The remaining gases in the combustion chamber are mixed with compressed air. This decreases the oxygen content of the new air-fuel mixture, which causes the HC emissions [29].

The HC emissions of biodiesels were compared with diesel. When biodiesel was compared to diesel in terms of HC, a decrease of 44.5% was observed in B20, 50% decrease was observed in B35, 53.50% decrease was observed in B50, 60.10% decrease was observed in B75 and 65%

decrease was observed in B100. The HC emissions for all fuels under all load conditions were calculated and given in Figure 6(a).



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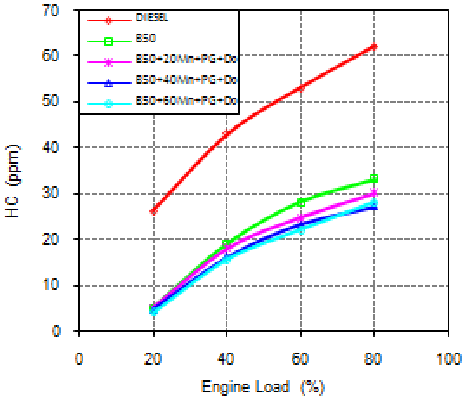


(b)

Figure 7. Variation of HC at different engine loads for various fuels. (a) Biodiesel, (b) B50 with additives

The decrease in HC emissions with the use of biodiesel is shown in Figure 7(a). This decrease is thought to be related to the oxygen content in biodiesel. The oxygen content in biodiesel is thought to support the combustion reaction, thus decreasing the HC emissions. The fact that every sample has varying amount of oxygen and the increase in cetane count in correspondence to the increasing biodiesel amount can be shown as the reason for this difference. With the increase in load, all of the fuels showed an increase in CO emission. This could be explained with the increase of the load causing a parallel increase in the fuel consumption.

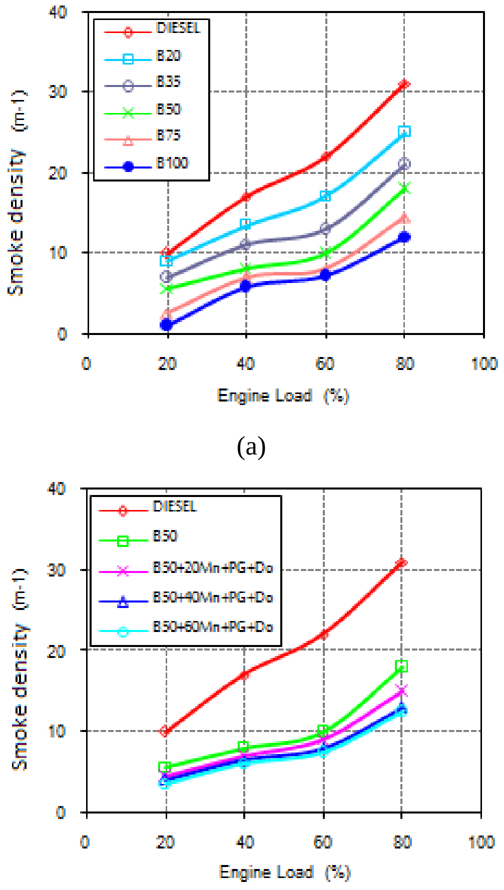
The oxygen content in biodiesel decreases the CO, HC and smoke emissions, because with the oxygen content, complete combustion takes place, and this contributes to decreasing HC emissions. In addition, the cetane count, boiling point, sulfur an aromatic content also have an effect in the HC, CO and smoke emissions.

The HC emissions of B50 fuel were compared to that of B50+20Mn+PG, B50+40Mn+PG and B50+60Mn+PG fuel. When the fuels are compared to the HC emission of B50, 4.90% decrease in B50+20Mn+PG fuel, 16.10% decrease was observed in B50+40Mn+PG, and a 15.60% decrease was observed in B50+60Mn+PG. The HC emissions for all fuels under all load conditions were calculated and given in Figure 7(b).

When additives are present in the fuel, the HC emissions decrease in comparison with B50, as seen in Figure 7(b). It is considered that the additives increase the cetane count and oxygen content, and contributes to improving combustion performance. The high oxygen content of propylene glycol and dodecanol's oxygen content and the effect of Mn on cetane count is considered to be the contributors.

CO_2 emissions are directly related with combustion. If the cylinder is working with a slow cycle, the combustion performance will be low, because the temperature in slower cycles is not optimal which causes a poor combustion reaction [29].

The smoke emissions of biodiesels were compared with diesel. When biodiesel was compared to diesel in terms of smoke emissions, a decrease of 19% was observed in B20, 35% decrease was observed in B35, 48.50% decrease was observed in B50, 60% decrease was observed in B75 and 67.50% decrease was observed in B100. The smoke emissions for all fuels under all load conditions were calculated and given in Fig. 8(a).



(a)

(b)

Figure 8. Variation of smoke density at different engine loads for various fuels. (a) Biodiesel, (b) B50 with additives

The reason that smoke emissions are lower when biodiesel is used could be explained by the oxygen content. Also, biodiesel has lower carbon count compared to diesel, which increases oxidation during combustion, that decreases smoke emission as a result. The decrease in smoke emissions with increasing biodiesel amount can be seen in Figure 8(a).

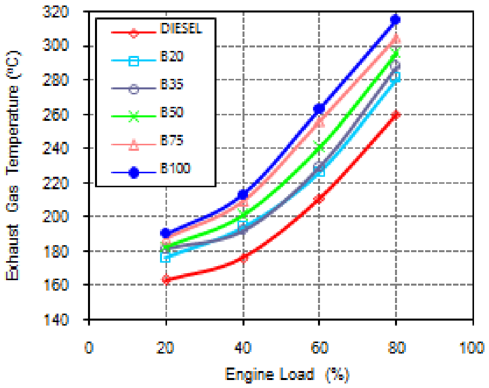
It is stated that the oxygen content of biodiesel causes a significant decrease in smoke emissions [25]. It is also stated that the lowered carbon content affects this situation. Oxygen containing fuels increase the temperature of the cylinder. This increase affects the combustion yield positively by preventing regional temperature difference. Changes in regional temperature and oxygen concentration distribution are considered to be the main reasons in soot formation [25].

The smoke emissions of B50 fuel were compared to those of B50+20Mn+PG, B50+40Mn+PG and B50+60Mn+PG fuel. When fuels are compared to the smoke emission of B50, 14% decrease in B50+20Mn+PG fuel, 23.50% decrease was observed in B50+40Mn+PG, and a 28.50% decrease was observed in B50+60Mn+PG. The smoke emissions for all fuels under all load conditions were calculated and given in Fig.8(b).

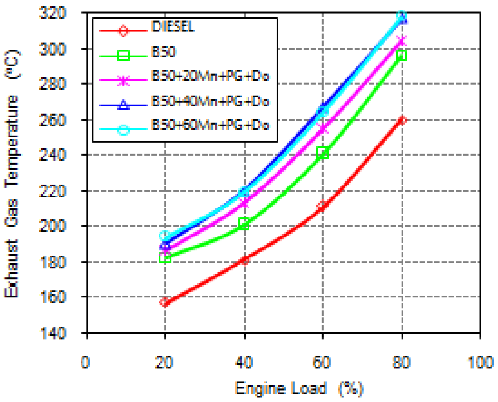
As seen in Figure 8(b), with the addition of additives, the smoke emissions decrease. The oxygen content of the additives is more than that of biodiesel. Supporting B50 with Mn, propylene glycol, and dodecanol decreases the carbon content and increases the oxygen content. It is considered that the increasing oxygen content speeds up the oxidation reaction and decreases smoke emissions [30]. Also, the additives give stability to the combustion reaction, which prevents turbulent mixing zones in the flame and smoke emissions.

Some of the heat energy gained by the combustion of fuel in the cylinder is lost to cooling, exhaust and friction. The remaining heat energy is converted to mechanical energy to provide power to the engine.

The exhaust temperature of biodiesels were compared with diesel. When biodiesel was compared to diesel in terms exhaust temperature, an increase of 8.5% was observed in B20, 10% increase was observed in B35, 14% increase was observed in B50, 18.50% increase was observed in B75 and 21.50% increase was observed in B100.



(a)



(b)

Figure 9. Variation of exhaust gas temperatures at different engine loads for various fuels (a) Biodiesel, (b) B50 with additives

Figure 9(a) shows that the exhaust temperatures have increased with increasing load. More heat energy is required to produce the necessary power for the engine. It is considered that high temperature causes high exhaust temperature. Figure 9(a) shows that the exhaust temperature increases with the use of biodiesel. The difference in the exhaust temperature of diesel and biodiesel is believed to be cause by the oxygen content in biodiesel and the high cetane count. It is thought that the test fuels gave a good combustion performance due to their oxygen content, and cause varying exhaust temperatures. Additionally, the high viscosity and cetane count causes a longer combustion, which can be presented as the reason for higher exhaust temperatures. It was stated that using biodiesel in diesel engines cause longer combustion, which results in exhaust with higher temperatures [29]. Exhaust temperature is affected by combustion lag and since biodiesel has a high cetane count, it presents a slower ignition lag period, and this causes increase in exhaust temperature when biodiesel is used [31].

The exhaust temperature of B50 fuel were compared to that of B50+20Mn+PG, B50+40Mn+PG and B50+60Mn+PG fuel. When the fuels are compared to the exhaust temperature of B50, 4.10% increase in B50+20Mn+PG fuel, 80% increase was observed in B50+40Mn+PG, and a 8.15% increase was observed in B50+60Mn+PG.

As seen on Figure 9(b), Mn, propylene glycol and dodecanol that has been added to B50 increases the exhaust temperature. As the additives increase the cetane count and oxygen content, they contribute in forming a high quality combustion characteristic. Higher cetane count causes a lower ignition lag that increases the exhaust temperature. The oxygen content in the chemical bond improves the combustion performance, which increases the exhaust temperature [29, 31].

3. Conclusions

In this study, methyl ester was produced from apricots pulp sources. The produced methyl ester was mixed with diesel in B20, B35, B50, B75 and B100 proportions, and was tested for engine performance and emission.

Based on the obtained results, the following conclusions can be drawn:

- The engine performance run by apricots seed methyl ester and its blends are comparable with the performance run by pure diesel fuel.
- When the aforementioned fuel samples were compared to diesel fuel, it was found that with increasing biodiesel content, the specific fuel consumption, exhaust temperature, NO_x and CO_2 emissions have increased partially, while the CO, HC and smoke emissions decreased significantly.
- Additionally, in the scope of this study, dodecanol, propylene glycol and Mn based additives were added to fuel B50 to improve the emission and engine performance values. With the presence of additives, an increase in the exhaust temperature and CO_2 emissions were observed, while a decrease in the specific fuel consumption, NO_x, CO, HC, and smoke emissions were detected.

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