

Effect of Second-Generation Biodiesel/Butanol Blends on Performance and Emission Characteristics of Diesel Engine

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Abstract: Biodiesel fuel is considered an alternative instead of fossil fuels to be used as fuel for diesel engines. Recently, the use of biodiesel fuel for diesel engines has increased because of its benefits, including the reduction of pollution resulting from these engines. So there is a great interest from researchers in the production of biodiesel from different ways of vegetable oils as well as animal fats. There are other trends for the production of biodiesel from used cooking oils in households and industries to preserve human food. The investigation study included a practical work of a 14 HP diesel engine to determine the performance of the engine fuelled with the used cooking oil biodiesel blended with butanol. Engine performance such as engine power - thermal efficiency - specific fuel consumption and pollutants emission such as CO, CO₂, HC, NO_x are also measured at different operating conditions. The experimental results showed that the use of diesel-biodiesel/butanol fuel is better than conventional diesel fuel. In general fuel blends contribute to enhance engine performance parameters, furthermore reducing the pollutants emitted from the engine, especially CO and HC. While there is a slight increase in the emission of CO₂ and NO_x as well as the engine power negatively will be affected at certain load conditions.

Keywords: Used cooking oil biodiesel, butanol, Engine performance, Emission

1. Introduction

Recently, scientists are interested in finding alternatives to traditional energy used in industry as well as transportation (Zahedi et al., 2024). This concern is due to two reasons: the first reason is depletion of potential fossil energy resources; the second reason is to protect the environment from pollution (Hosseini et al. 2017; Mourad & Mahmoud, 2019). The second reason is the most important, leading the international scientific community to direct researches to find alternatives to conventional energy. Pollution levels in densely populated countries have exceeded permissible limits, adversely affecting the environment and human health (Rao & Anand, 2016). Therefore transportation can be considered the main responsible for pollution within cities (Heydari-Maleney, 2017). The greater the density of vehicles within cities, leads to greater the pollutants in the atmosphere of cities. Transportation is also responsible for global warming due to carbon dioxide emissions (Tinprabath et al., 2016).

Therefore, there is a global concern to reduce the pollution caused by different types of the engines of vehicles. As a result of global attention to the pollution of the environment resulting from vehicles, Automobile factories as well as research institutes give great consideration to verdict new and renewable energy (Fattah et al., 2014). These alternatives should be renewable and reduce pollutants from vehicles. To achieve these goals, there are alternative means of fossil fuels (gasoline - diesel - gas) currently used in automotive. Among these alternatives is biodiesel fuel produced from vegetable oils, animal fats or used cooking oils. This research is concerned with the production of biodiesel fuel from used edible oils both in households or industries. This production method of biodiesel fuel is considered the second generation to produce biodiesel (Monirul, 2017). This kind of biodiesel gives great importance to the abundance of used vegetable oils in households or industries. This method also reduces the cost of producing biodiesel fuel, which makes the production process very economical, this gives the economic and environmental advantage of this type of biodiesel second generation. Literatures review also show the obvious interest of this type of biodiesel fuel as fuel for diesel engines.

Many researches have studied the production of biodiesel fuel from used oils, whether in households or industries, and to investigate their effect on the pollutants produced from these engines (Monirul et al., 2016). There is also a focus on studying the performance of diesel engines under different operating conditions that are powered by second-generation of biodiesel fuel. The following is a review of some of the available important previous studies, which concern the biodiesel fuel produced from edible oils used and its impact on the engine performance. Yesilyurt et al. (2018) studied the effect of fuel injection on performance emission of diesel engine fuelled with biodiesel blends at different engine speed. In this investigation the fuel injection pressure was changed from 170 to 220 bar. The results indicated that the engine power, carbon monoxide CO, Hydrocarbon HC decreased, otherwise the brake specific fuel consumption BSFC, Carbon dioxide CO₂ and Nitrogen oxides NO_x increased. Zhao et al. (2021) studied the influence of oxygenated biofuels (biodiesel – butanol) on diesel engine performance and its pollutants emission under conditions of two combustion modes, high temperature and low temperature combustion.

The results indicated that an improving in engine performance characteristics and emission. The performance characteristics and emitted pollutants of diesel engine under different engine loads and constant speed. Different alcohol-biodiesel blends (methanol-ethanol-butanol-propanol-pentanol) were applied as an alternative fuel for diesel engine to evaluate its influence on engine performance and emission. The results illustrated that CO₂, CO, HC, NO_x and PM decreased for all alcohol-biodiesel blends. Imdadul et al. (2016) studied the effect of biodiesel, butanol and pentanol on the engine performance and its emissions under different engine speeds. Different fuel blends were verified, including diesel.). The experimental investigation indicated that the blended fuels containing an alcohol improved the output power and BSFC. The results illustrated that CO and HC emissions in comparison with those of diesel fuel were reduced, while, the effect of pentanol was better than that of butanol on the engine performance characteristics and pollutants emission. Rajak & Verma (2018) seek out to evaluate emissions pollutants such as NO_x, particulate matter (PM) and summary of emissions (SE) from five different fuels such as, edible and non-edible vegetable oils, waste animal fats, waste oil and alcohol biodiesel.

Experimental works were conducted on a single cylinder, direct injection diesel engine at constant engine speed and injection timing. The results indicated clearly reduction of NO_x and PM emission while the diesel engine fuelled with different fuels. The results showed that the deepest value of NO_x emission for soybean (edible), jojoba curcas (non-edible), chicken fats (animal fats), grease oil (waste oil), butanol (alcohol) is decreased by 3050 ppm, 3003 ppm, 2680 ppm, 3280 ppm, 212 ppm respectively. Nabi & Rosul (2018) diesel engine performance, emissions, energy and exergy parameters were compared of three nonedible biodiesels blends and a conventional diesel. The experimental study carried out on 4-cylinder, 4-stroke, naturally aspirated direct injection diesel engine. The diesel engine was loaded and equipped with an eddy current dynamometer. Performance, emissions, energy and exergy parameters for the three biodiesel blends were compared with those of the reference diesel.

The result indicated that insignificant reduction in engine performance, an important reduction in total hydrocarbon (HC), carbon monoxide (CO), and particulate matter (PM) emissions. Nitrogen oxides (NO_x) emissions were increased with all three biodiesel blends. Wei et al. (2018) investigated experimentally the combustion process and NO_x emissions of waste cooking oil biodiesel on a marine auxiliary diesel engine. In this study the experiments were carried out on different blended ratios of biodiesel and diesel. The results indicated that the peak of heat release rate decreased with the increasing biodiesel blended ratios at different operation conditions. The significant reductions were 11.04% and 19.86% at engine speeds of 1050 rpm and 1500 rpm. BSFC increased but the brake thermal efficiency changed slight in the case of the biodiesel blended ratio increased. Previous studies show that researchers are interested in the effect of biodiesel fuel on the performance and pollution of engines.

The results indicate a significant reduction in pollutants from the diesel engine when fuelled with biodiesel. The results also revealed some of the disadvantages of the engine as a result of the use of biodiesel fuel produced from the oils used. Therefore, this current study seeks to investigate the influence of blending biodiesel with different percentages of alcohol such as butanol. The chemical composition of butanol includes a percentage of oxygen, which improves combustion process within the cylinder of diesel engine.

Therefore the use of different blends of diesel, biodiesel and butanol can improve engine performance. Different mixtures of biodiesel and butanol (0 - 10 - 20 - 40 – 50%) are used to operate the engine and thus determine its performance and the emitted pollutants. To complete this experimental study, a 14 HP diesel engine was equipped with the necessary instrumentations and measurement devices to accomplish the experiments. Practical experiments of different blends of biodiesel and butanol were carried out at different loads (0-25-50-75-100%) and at constant engine speed 1500 rpm. During the carrying-out of various experiments of the diesel engine with different blends, the surrounding operating conditions should be fairly steady in order to ensure the accuracy of the experimental results. The experimental results concerned the effect of these different blends on the performance of the engine (engine torque - thermal efficiency - specific fuel consumption - volumetric efficiency - exhaust temperatures) as well as the emission of pollutants (CO – CO₂ - HC – NO_x). The results indicated that fuel blends give an attempt to enhance engine performance parameters, furthermore decreasing the pollutants emission from the engine, especially CO and HC.

2. Material and Methods

2.1 Biodiesel Production

To complete the process of producing biodiesel fuel from used edible oils in household or industry, there are several processes to produce biodiesel. These methods are very similar to the methods of producing biodiesel fuel from pure oils (Abedin et al., 2016). The following is a summary of the physical and chemical procedures used to produce biodiesel from used oils. First, an adequate and sufficient quantity of household oils is brought for the purpose of conversion to biodiesel fuel. It should be considered that the source of the used oil is a certain source to ensure that the physical and chemical specifications of the oil are constant. The used oil is well filtered from the impurities in several stages to ensure oil purification. The filtered oil is heated up to a temperature of 55-65 °C degrees Celsius. Meanwhile, a methanol mixture with potassium hydroxide is prepared according to the acidity test for the oil used. The acidity determination test is especially important when converting the oils used to determine the amount of potassium hydroxide required for the completion of the esterification process. The acidity of the oil used shall be measured between 8-9 HB by preparing the caustic soda solution (adding 1 gram of caustic soda to 1 liter distilled water).

Add 10 mL of isopropyl alcohol to 1 mL of preheated oil to be converted. Carefully add the caustic soda solution as drops to the isopropyl alcohol mixture and oil until the pH reaches to 8-9. The quantity of potassium hydroxide required to complete the process of conversion of oil used to biodiesel fuel is calculated accordingly. The methanol and potassium hydroxide mixture is processed according to the amount of oil to be converted, mixing 7.0 grams of potassium hydroxide to 200 mL of methanol to convert one liter of used oil (Tongroon et al., 2017).

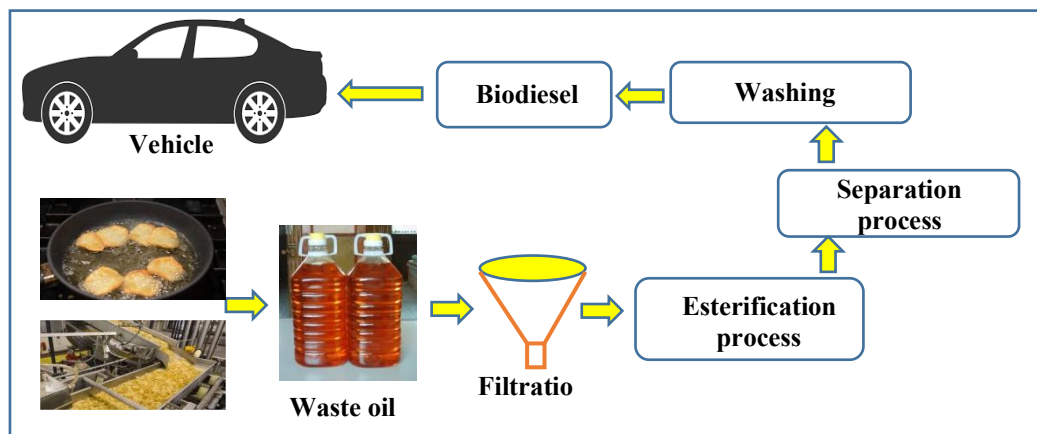


Figure 1. Schematic diagram of waste biodiesel production process

2.2 Experimental Setup Description

Laboratory tests were carried out on a diesel engine with a power of 14 hp, single cylinder, Four-stroke, air-cooled connected to an electric generator. The technical details of the diesel IC engine are detailed in Table 2. Figure 2 illustrates the schematic diagram of the diesel engine and instrumentation systems.

In order to identify and measure the performance characteristics and emissions of the engine fueled with blend of diesel, biodiesel produced from used cooking oils and butanol (Martínez et al., 2014). The diesel engine is also equipped with the necessary measuring tools and instruments to complete the research study. All devices such as (fuel consumption meter, exhaust gas analyzer, digital thermometer, engine speedometer, air flow meter, etc.) are connected to the engine, prepared and calibrated to complete the measurement process.

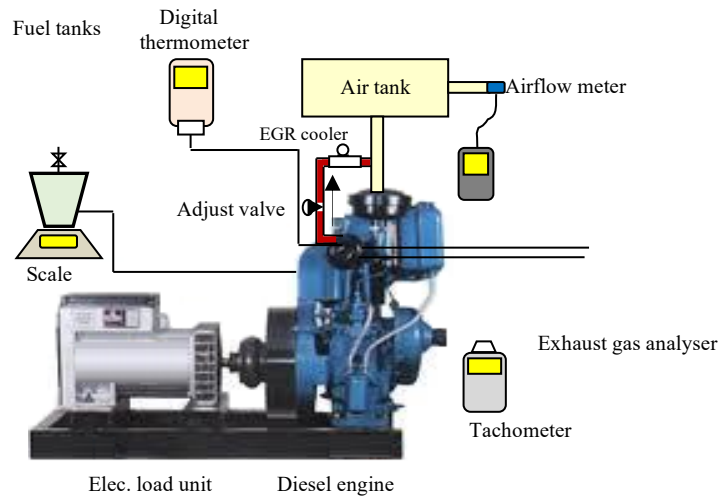


Figure 2. Schematic diagram of the diesel engine with instrumentations system

Table 1. Technical specification of CI engine

Engine parameter	value
Engine type	diesel
Displacement, cm ³	1190
Number of cylinders	1
Compression ratio	15
Bore / Stroke, mm	114/116
Injection pressure, bar	220
Injection timing, BTDC	23°
Cooling type	Air
Max.power kW@rpm	10.4@1500

2.3 Experimental Test Conditions

To ensure the accuracy of practical measurements, all laboratory experiments were performed under the same operating conditions and surrounding factors. All measuring devices used to record output data; performance parameters and pollution were calibrated. The accuracy of the measuring instruments, the error analysis and the uncertainty of each instrument were also examined as shown in the table. Experimental weather conditions are periodically recorded before and during experiments to ensure that the surrounding conditions are stable. The air temperature, relative humidity and density of the air are recorded in the test laboratory (20 ° C - 50: 55% - 1.18 kg / m³, respectively). The engine is heated long enough to ensure that the engine reaches optimum operating temperatures (for example, engine oil temperature 77-84 degrees). Experiments are conducted more than once to verify the accuracy of the results and reduce measurement errors. Table 3 shows the different degrees of accuracy and uncertainties in the measured properties. Table 4 shows experimental test conditions. Table 5 shows the technical specifications of the exhaust gas analyzer.

Table 2. Accuracies and uncertainties of the measured properties

Property	Accuracies	Uncertainties
Load	± 0.2 N	± 0.2 %
Power	-	± 0.2 %
Fuel consumption	±2.0 g/h	± 1.5 %
Air flow rate	±1.0 cm ³ /h	± 0.2 %
BTE	-	± 2.5 %
Engine speed	±15 rpm	± 0.5 %
Temperatures	± 1 ° C	± 0.1 %
Carbon monoxide	± 0.15 g/kWh	± 0.2 %
Hydrocarbon	± 0.10 g/kWh	± 0.2 %
Carbon dioxide	± 0.50 g/kWh	± 1.0 %
Nitrogen oxides	± 0.10 g/kWh	± 0.2 %

Table 3. Tests conditions

Parameter	Value
Engine speed, rpm	1500
Engine load, %	50
Ambient temperature, °C	30
Relative humidity, %	50 to 55
Air density, kg/m ³	1.18
Lubricating oil temperature, °C	77 to 84

Table 4. Exhaust gas analyzer specifications

Property	Value
Type	Infrared industries FGA4000SDX
Gases measured	HC, CO, CO ₂ , O ₂ and NO _x
HC range	0-10000 ppm
CO range	0-10 %
CO ₂ range	0-25 %
NO _x range	1-5000 ppm
A/F	0-50 %
Lambda	0-5

3. Results and Discussion

3.1 Results of Engine Performance Characteristics

The performance, combustion and emission characteristics of the diesel engine were performed when running on diesel fuel and various mixtures of DBI and constant speed of 1500 rpm on different operating conditions. The results include: thermal efficiency, specific fuel consumption, exhaust temperatures and emissions. Carbon dioxide, nitrogen oxides, hydrogen and smoke were analysed and these results were compared with diesel fuel.

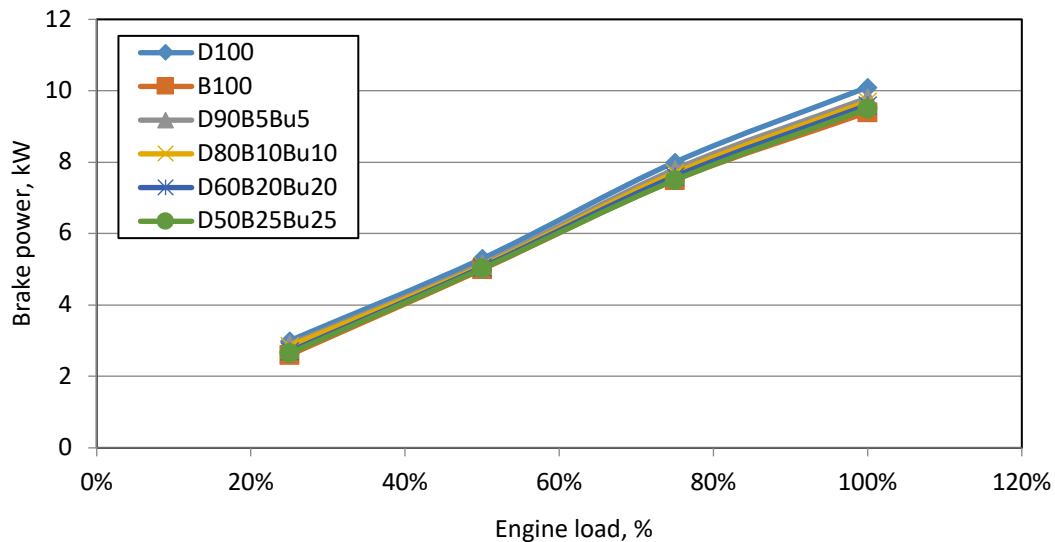


Figure 3. Effect of engine load on engine brake power for different fuel blends

Figure 3 provides the relationship between engine power and the loads acting on engine for various fuel mixtures between diesel, biodiesel and butanol. It can be seen from the figure that as the load acting on the engine increases from 25 to 100 %, the value of the power exiting the engine increases for all fuel blends. The value of the engine's power ranges between 2.6 to 10 kW, according to the load acting on engine. The higher the load, the higher the power is required for the engine. As the power of the engine is affected by many parameters, including the efficiency of combustion, the heating value of the fuel, the number of cetane, how the fuel is mixed in the combustion chamber and other factors that have a direct and indirect effect on the engine's power. It can be observed that there are slight differences in the engine power for different types of fuel blends, and this appears in the area of high loads, as shown in the figure.

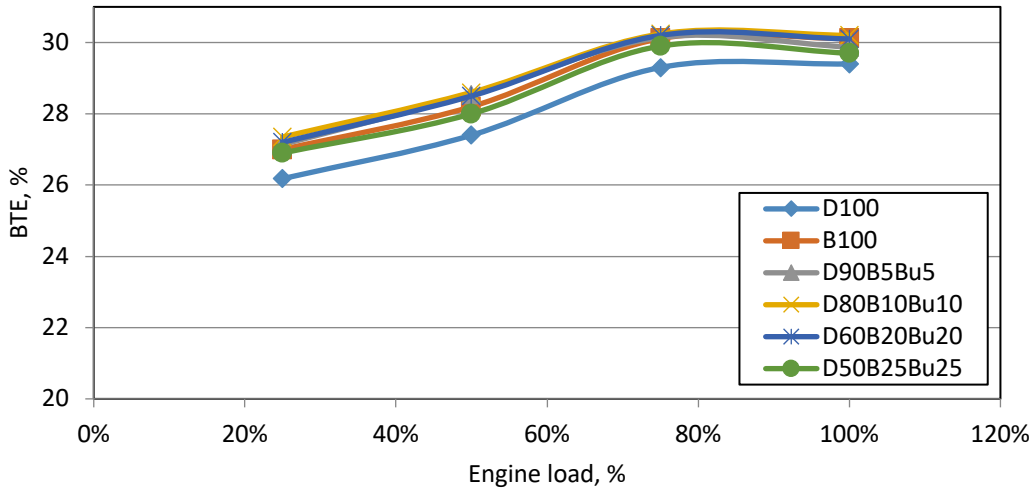


Figure 4. Effect of engine load on brake thermal efficiency for different fuel blends

Figure 4 shows the relationship between the brake thermal efficiency (BTE) of the engine with different engine loads from 25 up to 100 % for different types of fuel blends. The thermal efficiency of the diesel engine is one of the most important factors that indicate the behaviour of the engine and the efficiency of combustion inside the combustion chamber of the engine (Saba et al., 2016). As the thermal efficiency is directly affected by the brake power of the engine, and inversely, with both the engine's fuel consumption and the calorific value of the fuel. The higher the engine's power, the better the thermal efficiency and the higher its value, as well as the lower the engine's fuel consumption, the higher the thermal efficiency, especially in the high loads of operating conditions. Figure 5 shows the specific fuel consumption with engine load (from 0% to 100%) for different mixtures of biodiesel, butanol and diesel. It can be observed from the results as shown that pure diesel fuel gives the lowest specific fuel consumption; while a diesel mixture of (D80B10Bu10) gives the lowest specific consumption of the different mixtures.

This can be explained by several reasons, including that diesel fuel is less viscous than different mixtures. It is more dissolved in the combustion process inside the engine room, and therefore the quality of the fire was improved, which leads to an increase in the efficiency of the engine and thus a decrease in specific fuel consumption. Also, the lower heating value of diesel fuel is higher than that of different fuel blends, which makes the energy released from the same fuel molecules for different types differ, and thus the amount of fuel consumed is less for the same amount of energy released during the combustion process inside the engine room. The lowest specific fuel consumption values for different mixtures range from 305 to 310 g/kWh. The results prove that the fuel mixture (D80B10Bu10) was the optimal alternative for the different mixtures among all the tested fuels.

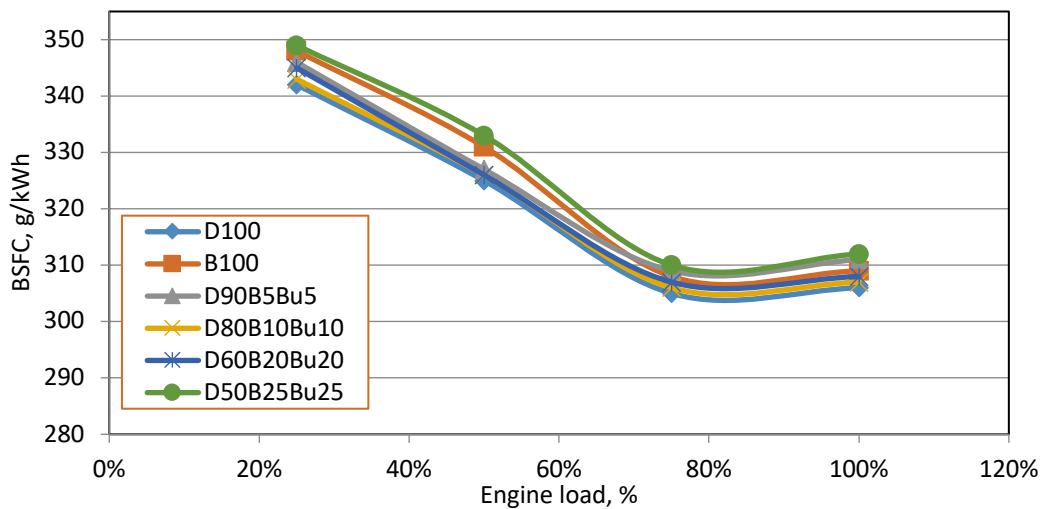


Figure 5. Effect of engine load on BSFC for different fuel blends

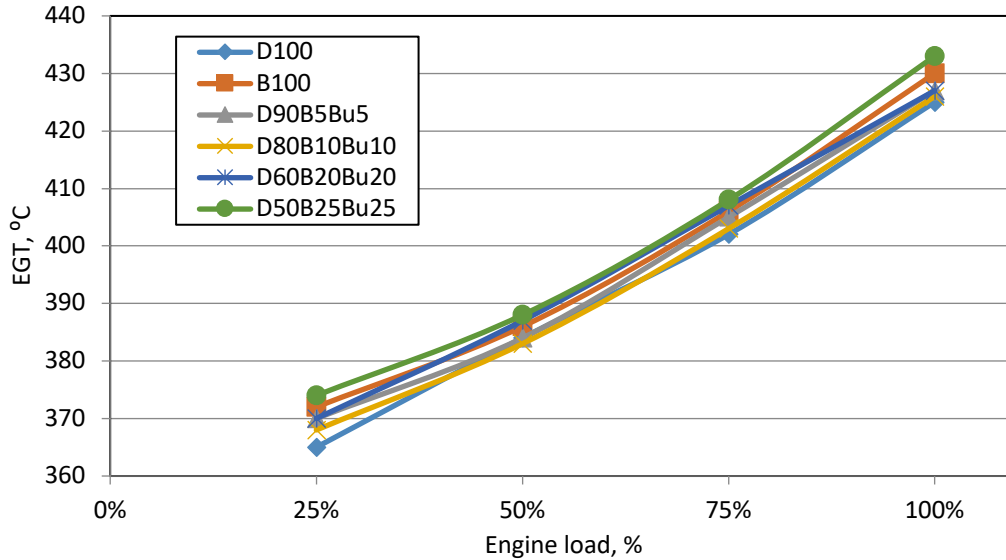


Figure 6. Effect of engine load on exhaust gas temperature for different fuel blends

The exhaust temperatures for different types of fuel mixtures after being emitted from the engine illustrated in Figure 6. This figure is important as it is somewhat indicative of what is happening inside the engine's combustion chamber. The better the combustion inside the combustion chamber, the higher the heat energy generated from the combustion process, and therefore the exhaust temperature is relatively high. The figure shows that exhaust temperatures are between 365°C and 432°C at full load for all fuel blends used to operate the engine. The exhaust temperature difference at the different loading points is 10°C. The lowest exhaust temperatures are for pure diesel fuel, then for fuel blend D80B10Bu10.

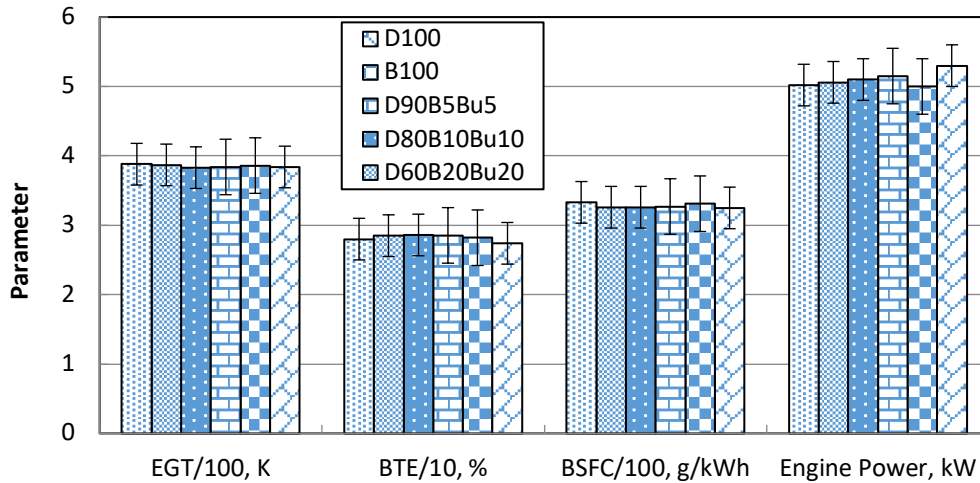


Figure 7. Engine power, EGT, BTE and BSFC for different fuel blends at 50% of engine load

Figure 7 represents the different external performance parameters (EGT, BTE, BSFC and Engine power) of the diesel engine when running with different fuel blends so that the results can be compared with conventional diesel fuel. This comparison was conducted at 50 % engine load and 1500 rpm engine speed to determine the influence of different fuel blends on engine performance. It was detected in the figure for the results of the comparison of the exhaust temperatures of the different types of fuel blends that the exhaust exit temperatures are similar, and the pure diesel fuel and the fuel mixture (D80B10Bu10) give the lowest exhaust temperatures, which gives good results on the different exhaust emissions. The thermal efficiency of the engine improves for the fuel mixture (D80B10Bu10) and (D90B5Bu5) due to the improvement of the combustion properties inside the combustion chamber as a result of the oxygen content in biodiesel as well as butanol, which increases the quality of combustion.

The value of the brake thermal efficiency of different fuel blends range from 27.4 % to 28.6 % and the percentage of improvement compared to diesel fuel is 4.3. Specific fuel consumption is one of the most important external characteristics that determine the quality of engine performance under different operating conditions for different types of fuel blends. It can be noticed in the figure that the specific consumption of diesel fuel is as low as possible, and this can be explained by the fact that the calorific value of diesel fuel is high, and therefore the amount of energy resulting from its combustion is large, and therefore the value of the output power generated by the engine increases, so the value

of specific fuel consumption is low. It gives the lowest value for specific fuel consumption compared to the rest of the fuel mixtures. This can be attributed to the improvement in the combustion quality inside the engine combustion chamber, as the mixture contains biodiesel and butanol fuel, which increases the oxygen content as well as the ease of atomizing the fuel vapour inside the combustion chambers that increase the mixture homogenous. The results of the power output from the engine when fed with different fuel mixtures, pure diesel fuel gives the highest power value than the rest of the fuel mixtures, due to the calorific value of diesel fuel is (52 MJ/kg) higher than the rest of the fuel mixtures.

3.2 Results of Engine Emission Characteristics

Figure 8 shows the emission of carbon dioxide (CO₂) at different engine loads for the internal combustion engine while it is running with different types of fuel blends. It is clear from the figure that the emission of CO₂ for all different fuel blends is between 960 g/kWh and 1150 g/kWh. The figure also shows that the value of CO₂ emission is an increase in the case of using pure biodiesel fuel, while it is at its lowest value when using pure diesel fuel. This is due to the fact that the heating value of diesel fuel is higher than that of biodiesel fuel, so higher fuel consumption is used in the case of biodiesel at the same load, and therefore there are more carbon dioxide emissions. It can be seen from the figure that CO₂ is high at low loads and then the carbon dioxide value decreases with the increase in the engine load. This is because the units of CO₂ are measured in relation to the power produced by the engine, so that the value of carbon dioxide emission is in g/h with increasing load, while when divided by the power produced by the engine, the values for CO₂ emission decrease. It can also be seen from the figure that CO₂ emission is less than the possible for the D80B10Bu10 mixture than the rest of fuel blends. This can be explained by the fact that the percentage of adding 10% Biodiesel and 10% of butanol gives the best blending so that the percentage of oxygen content helps to enhance the combustion process, which increases the quality of combustion for a lower amount of fuel, and thus the emission of CO₂ is less than its counterparts [41].

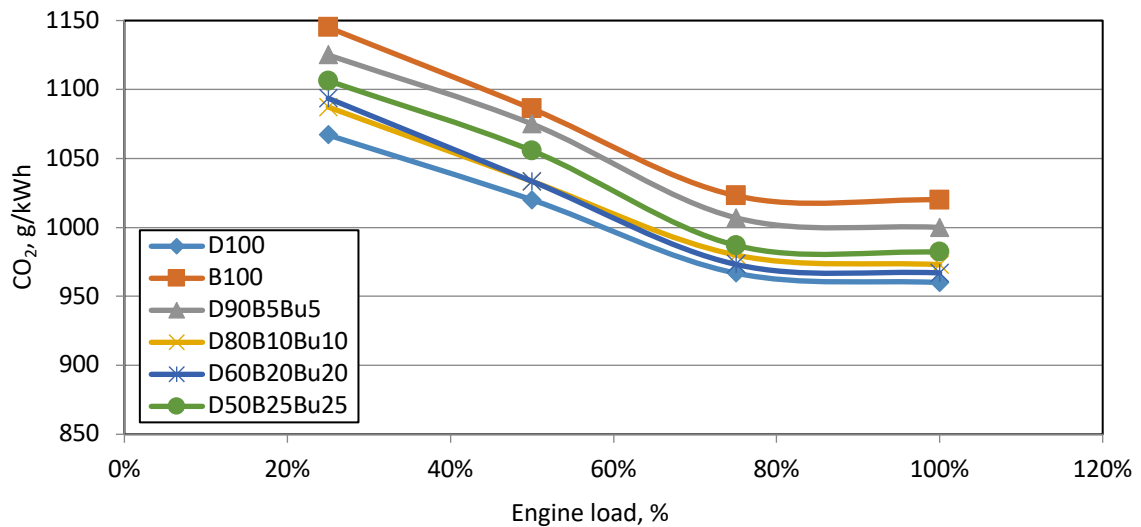


Figure 8. Effect of engine load on CO₂ emission for different fuel blends

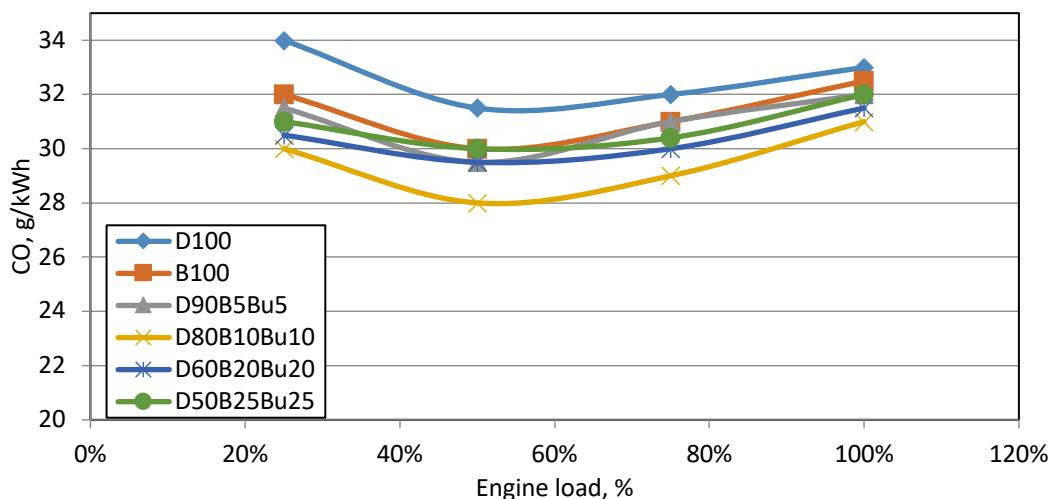


Figure 9. Effect of engine load on CO emission for different fuel blends

Figure 9 displays CO emissions of different diesel/biodiesel/butanol blends under different engine load conditions and at an engine speed of 1500 rpm. CO is formed inside the combustion chamber of the engine during combustion, due to the lack of sufficient amount of oxygen or air, as well as due to the low temperature of the flame, which increases the chance of producing carbon monoxide. It can be seen that CO emission increases with increasing engine load. This can be explained by the increase in CO emissions with load as a result of the increase in the air-fuel ratio, as well as by the high temperature in the combustion chamber and the lack of oxygen at high speed and the narrow combustion time. All of these factors lead to the incomplete combustion inside the engine room properly, and thus there is an increase in the proportion of carbon monoxide emission from the engine. It is clear that B100 gives lower carbon monoxide emissions than pure diesel and the rest of the fuel blends due to the high oxygen content, which leads to an increase in the temperature in the combustion chamber, which improves the process and quality of combustion inside the engine room, which leads to more conversion of CO to CO₂.

The (D80B10Bu10) fuel blend gives the lowest CO emissions during different engine loads as it emits 37.5% carbon monoxide due to its high oxygen content, which leads to an increase in the temperature in the combustion chamber, which gives an opportunity for the combustion to complete, resulting in reduction in CO₂ emission.

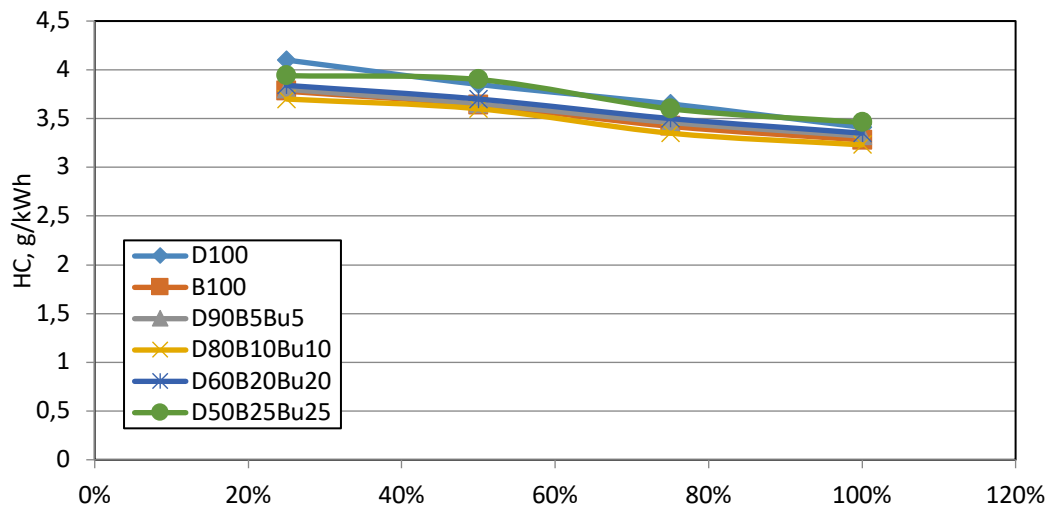


Figure 10. Effect of engine load on HC emission for different fuel blends

Figure 10 shows a variance in the unburned hydrocarbon HC emissions for different mixtures of diesel, biodiesel and butanol at different loads and 1500 rpm engine speeds. HC arises mainly inside the combustion chambers of a diesel engine due to incomplete combustion due to the increase in the proportion of fuel to air, which does not allow all the fuel particles to fully combust. HC emission depends on the characteristics of the fuel, the conditions inside the cylinder, and the mixture of air and fuel. The (D80 B10 Bu10) mixture has lower HC emissions compared to pure diesel, and this may be due to a lower cetane number, a lower temperature in the cylinder and incomplete combustion, as well as a lower pressure of the burning gases with the heating of the combustion chamber due to the slow spread of the flame.

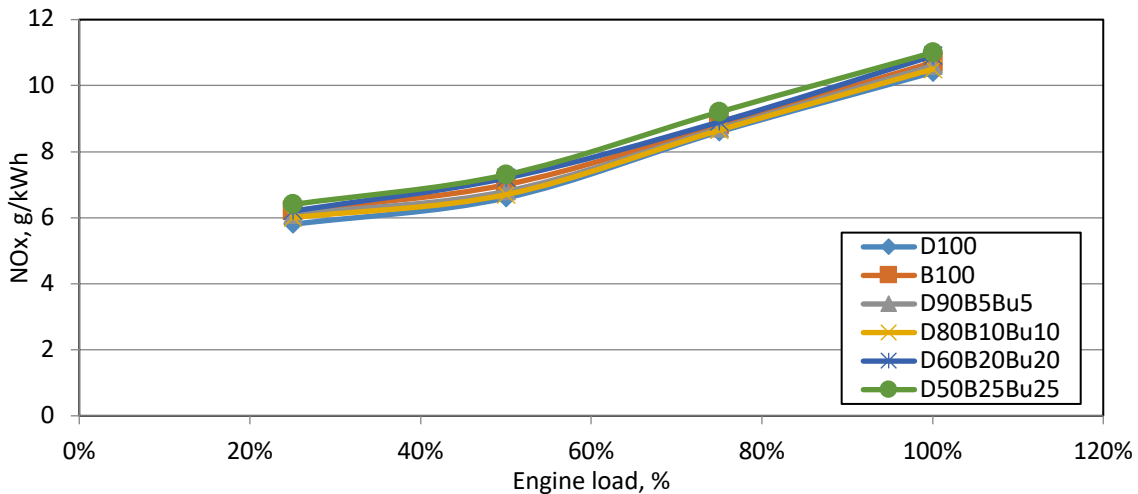


Figure 11. Effect of engine load on NO_x emission for different fuel blends

This is because the mass of the injected fuel increases with the increase in engine load while the engine inlet air flow rate is little. This caused a decrease in the air-fuel ratio as the engine load increased, as shown in Figure 11. Increasing the richness of the fuel-air mixture with increasing engine load led to an increase in the maximum pressure of the burning gases inside the engine cylinder, as shown in Figure 11, in addition to an increase at maximum cylinder temperature resulting in an increase in NO_x emissions with increased engine load. Also, it shows that NO_x emissions increased slightly when oxygenated fuels were used as alternatives to diesel under most engine load conditions. Generally, using neat biodiesel (B100) or different fuel mixtures of diesel, biodiesel and butanol results in slightly higher NO_x emissions compared to diesel fuels tested for most engine load conditions. NO_x emissions of the fuel blends are less than B100 due to the lower cetane number, lower LHV, and higher latent heat of evaporation of butanol. It can be increased the ignition delay and reduce combustion temperature. Moreover, the higher oxygen content of butanol accelerates the combustion speed and shortens the reaction time of combustion gaseous, thus resulting in lower NO_x emissions for different fuel blends comparison with biodiesel fuel.

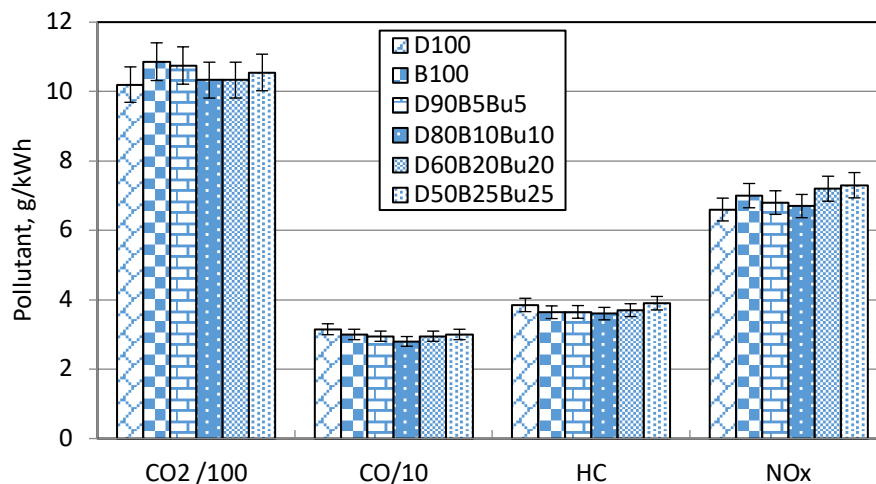


Figure 12. Pollutants emission (NO_x, HC, CO, CO₂) for different fuel blends at 50% of engine load

Figure 12 shows the emissions of different pollutants (NO_x, HC, CO, CO₂) for different fuel mixtures at 50% engine load and engine speed 1500 rpm. It is clear from the NO_x emissions that the lowest value is for diesel fuel compared to all mixtures, so the value of NO_x emission for diesel fuel is 6.4 g/kWh. While the lowest value for NO_x emissions for different mixtures is for a mixture (D100, B100, D90B5Bu5, D80B10Bu10, D60B20Bu20, D50B25Bu25) due to the oxygen content in biodiesel and butanol, which helps in the increase of NO_x emissions (Wang et al., 2015). NO_x emissions are lower than those of other mixtures.

HC emissions are close to all fuel mixtures, and their values are lower for mixtures (D80B10Bu10) due to the presence of oxygen content, which helps to improve combustion, and thus the percentage of HC emission decreases. Also, CO emissions are clearly affected by the presence of the oxygen ratio in the mixture, which provides opportunities for the combustion to be completed inside the combustion chamber, and this is clearly evident in the different fuel mixtures and the lowest CO emissions for a mixture (D80B10Bu10). The figure also shows the CO₂ emissions of diesel fuel and various fuel mixtures, and where the CO₂ emission is a direct reflection of the specific fuel consumption in the engine, the higher the fuel consumption, the higher the CO₂ emission as a result of combustion, so it is considered a direct relationship. It is noted from the figure that CO₂ emissions are less valuable for diesel fuel, followed by a mixture (D80B10Bu10), which can be explained because of the calorific value and oxygen content, which leads to an improvement in the fire condition inside the engine room and thus reduces specific fuel consumption, which leads to a decrease in CO₂ emissions from the engine for this mixture (Agarwal et al., 2016).

4. Conclusions

By reviewing the practical results, there are results that can be extracted from this scientific paper, which is concerned with studying the effect of different fuel blends with different mixing ratios on engine performance, as well as pollutant emissions to the surrounding environment at different operating conditions. Where this experimental work seeks to find types of biofuel blends to look for enhance the efficiency of the thermal engine and improving the various performance parameters, it is also a vigorous attempt to reduce the pollutants emission resulting from diesel engines.

- a. A survey and review of many of the previous studies concerned with bio-fuel mixtures and their impact on the characteristics and performance of the engine were conducted. Through these reviews, the types of biofuel blends were known and their impact on the emissions of pollutants from the engine, as well as the different

- performance characteristics under different operating conditions. It also identified the points of shortcoming in those scientific papers, which have not been studied extensively.
- b. Practical experiments were conducted on a 14 HP diesel engine, at different loads and an engine speed of 1500 rpm. Also, bio-fuel was produced from used edible oils, as well as the different mixing ratios of diesel fuel with bio-fuel and butanol were determined.
 - c. It is clear from the results that the engine output-power of diesel fuel is noticeable higher than that of different biofuel blends. While there is a slightly decrease in the specific fuel consumption of a mixture (D80B10Bu10) compared to the rest of the different types of different fuel mixtures, and the percentage of decrease is up to 2.14 %. The results also show that there is an improvement in the thermal efficiency of the engine when using bio-fuel mixtures at the expense of conventional diesel, and the improvement percentage is 4.0 % for a mixture (D80B10Bu10) over diesel fuel.
 - d. Through the results that review the pollutants resulting from the engine when using conventional diesel fuel and various biofuel mixtures, a clear improvement can be observed in the engine emissions of the pollutants CO and HC. In general, there is a lower emission of CO and HC for biofuels compared to conventional diesel fuel, and the reduction ratio between diesel fuel and biofuel blends (D80B10Bu10) is 12.5% and 6.9 % for each of the CO and HC, respectively.
 - e. It is evident from the results of the NOx emissions that the fuel blend (D80B10Bu10) gives the best results for NOx emissions compared to the rest of the fuel blends, and the percentage of reduction is up to 8.95 %. While there is a somewhat increase in the emission of NOx if the results are compared with conventional diesel fuel, and the value of the increase is 1.5 %.
 - f. Through the results presented in this research paper that was conducted on many biofuel mixtures compared to conventional diesel fuel, it can be concluded that biofuel gives clear improvements to the performance parameters of the diesel engine, as well as there are clear decreases of pollutants, especially CO and HC resulting from the combustion engine under operating conditions. Accordingly, fuel blend (D80B10Bu10) is the best fuel mixture and is recommended to be used as engine fuel.

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Conflict of Interest

The author declare no conflict of interest.

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