Effect of n-Butanol Blends on Engine Performance and Exhaust Emission of Compression Ignition Engine Fuelled with Diesel-Palm Oil Methyl Ester (B20)

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Abstract. The study aims to evaluate the performance and emission characteristic in a compression ignition engine of conventional diesel fuel-biodiesel blends with different percentage of fuel additive n-butanol. The experiment was operated at a constant engine load (50% throttle condition) with different engine speed (2700, 3100, 3500 rpm). A blend of biodiesel and diesel fuel known as B20 (20% palm oil methyl ester and 80% diesel in volume) was prepared, and then n-butanol was added to B20 at a volume of 5ml, 10ml and 15ml (denote as B20+Bu5, B20+Bu10 and B20+Bu15, respectively) and the tested fuel samples were compared with diesel fuel and diesel-biodiesel (B20). The experimental results show that when the proportion of n-butanol was increased in B20 blends, kinematic viscosity was larger while calorific value was smaller than those of the neat diesel. Although n-butanol have some negative impacts on engine performance parameters, its generally positively affect exhaust emission parameters compared to diesel fuel. According to engine performance and exhaust emission test result of n-butanol fuel blends with B20 blends, average values of brake thermal efficiency (10.19%, 7.58% and 4.29%), carbon monoxide (21.75%, 17.06% and 11.28%), hydrocarbon (18.51%, 15.68% and 12.13%) are lower, while brake specific fuel consumption (BSFC) (27.48%, 45.37% and 59.20%) are higher and carbon dioxide (CO2) and oxides of nitrogen (NOx) are comparable than those of diesel fuel.

Keywords: renewable energy, biodiesel, n-butanol, palm oil methyl ester

1. Introduction
The compression ignition engine, also known as diesel engine, is the most commonly used in industries and automobile due to its capability for heavy duty application [1,2] and because of their high fuel conversion efficiencies and durability. It has a higher brake thermal efficiency than spark ignition (SI) engines [3]. This type of engine is one of the main users of diesel fuel. The demand of diesel fuel has been growing constantly because the diesel engines are more efficient, use relatively less fuel per engine effective power unit and have a less impact on the environment compared to petrol engines. However, the limited amount of fossil fuels and pollutants emission resulting from diesel combustion have
negative effects on both human health and the environment. This has led researchers to investigate a new alternative and renewable energy sources that suitable for the diesel engine to operate [4].

Alternative fuel is a fuel for internal combustion engines that is derived partly or wholly from a source other than petroleum and that is less damaging to the environment than conventional fuels (fossil fuels). Some examples of alternative fuels are natural gas, biodiesel, methanol, ethanol, vegetable oil, biomass and others [5, 6] are potential candidates to reduce fossil fuel consumption, exhaust emission, and global warming in the future. Currently, biodiesel is one of the alternative fuels which is widely used biofuel for diesel engines which have been examined by previous researchers [7, 8]. Biodiesel is generally derived from a variety of vegetable oils and animal fats. It is a diesel fuel substitute that can be used in diesel engines without modifying the engines. Biodiesel is cleaner, produces fewer emissions and is a viable alternative energy source. Moreover, biodiesel is less toxic fuel, biodegradable, renewable, non-explosive and emit less air pollutant compared to mineral diesel [9]. This alternative fuel designed to extend the usefulness of petroleum and diesel engine longevity and cleanliness [10, 11]. However, biodiesel produce lower engine power because it has less energy per unit volume than diesel fuel. The fuel efficiency tends to be slightly lower when using biodiesel due to the lower energy content of the fuel [10], [12-14]. Biodiesel also slightly increase in nitrogen oxide emission compare than diesel fuels. Therefore, fuel additives such as alcohols are used to improve the fuel properties [10, 11], [5].

Fuel additives are chemical formulated compounds to improve the quality and efficiency of fuels in motor vehicles. The fuel additives increase a fuel's cetane rating or act as corrosion inhibitors or lubricants, thus allowing the use of higher compression ratios for greater efficiency and power. For biodiesel, the biodiesel fuel additive which have higher oxygen content are blends in biodiesel to enhance the performance of engine and reduced the brake specific fuel consumption (BSFC). One of the examples of fuel additives are is alcohol n-butanol. Butanol (C₄H₁₀O), which is known as butyl alcohol is an alcohol that comprised of a four-carbon structure [17]. It is a clear and colourless liquid with a four-carbon straight-chain structures. The demand for butanol nowadays is due to its usable as biofuel. Butanol have been used as blending component in diesel fuels due to its higher miscibility [16]. the lower viscosity and higher volatility in alcohols would be improved with the addition of biodiesel. Furthermore, the increased oxygen content of the blended fuel can improve the combustion process. Butanol can be used as biodiesel additive due to high oxygen content in it [8],[11],[16],[18]. It has a high cetane number compare to some alcohols [10], good solubility and higher heat content appeal many researchers to consider butanol as an additive to biodiesel blends [18],[19]. However, the use of butanol as fuel additive has found increase the brake thermal efficiency (BTE) and the BSFC of the engine which is stated by previous researchers [10],[18]. Additional of n-butanol in fuel blends also found reducing the exhaust emissions such as nitrogen oxide (NOx), carbon monoxide (CO) and particulate matter (PM) except for hydrocarbon (HC) emissions [20].

Hence, the aim of this research is to study the engine performance and emissions profile of compression ignition engine fuel with palm oil methyl ester (B20) blends with alcohol butanol with various of proportions. The fuel blends were tested for some important properties such as density, kinematic viscosity and calorific value. Engine performance parameters such as brake thermal efficiencies and specific fuel consumption were investigated. The emission of CO, CO₂, HC and NOx were also considered in this study. Thus, the objective of this study was to evaluate the potential of diesel-palm oil methyl ester-n-butanol ternary blends as an alternative to diesel fuel. In addition, the effect of n-butanol proportion on combustion and emissions was investigated. The current study adds importance to the topic of ternary blends and may support the idea of using ternary fuel blends of diesel-biodiesel-n-butanol in CI diesel engine in the future.
2. Experimental Setup

2.1. Sample Preparation

There are five samples that were used in this experiment which are 100% diesel fuel (D100) which will be a baseline reference for this research to compare with other fuel blends, B20 (80% diesel fuel + 20% Palm Oil Methyl Ester biodiesel), B20+Bu5, B20+Bu10 and B20+Bu15 (B20 palm oil methyl ester + 5ml, 10ml, 15ml n-butanol respectively). The biodiesel Palm Oil Methyl Ester was obtained from the Automotive Lab at Faculty of Mechanical Engineering (FKM) whereas alcohol n-butanol was obtained from chemical lab at Faculty of Chemical Engineering (FKK) in UiTM Shah Alam. The preparation of fuel properties for the fuel blend was examined at the Instrumentation Lab in Faculty of Chemical Engineering, UiTM Shah Alam. The calorific value, viscosity and density of the fuel blends are the properties that have been identified at the lab which will be discussed further in results of the experiment.

The density for the fuel blends were calculated by obtaining the mass of 1mg each of the fuel blends via analytical balance, then calculate by using density formula. After obtaining the densities, calorific value of the fuel blends was evaluated via bomb calorimeter machine. For the kinematic viscosity, those values were obtained by dividing the dynamic viscosity of the fuels with its density. The dynamic viscosity of the fuel blends was obtained via physical rheometer at chemical lab, FKK. The fuel properties data that obtained from FKK are tabulated in table 1 below.

| Fuel              | D100 | PME | B20 + 5 ml n-Butanol | B20 + 10 ml n-Butanol | B20 + 15ml n-Butanol |
|-------------------|------|-----|----------------------|-----------------------|----------------------|
| Density (kg/m³)   | 0.9220 | 0.9590 | 0.8782               | 0.9229               | 0.9536               |
| Calorific Value (MJ/kg) | 44.496 | 39.515 | 39.328               | 39.114               | 38.946               |
| Kinematic Viscosity (m²/s) | 0.00362 | 0.00515 | 0.00512             | 0.00476             | 0.00435             |

2.2. Engine Test Performance

The experiment was conducted at Automotive Workshop, Faculty of Mechanical Engineering, University Teknologi Mara (UiTM) Shah Alam. The experiments were performed by using a single cylinder, four stroke, air cooled, compression ignition engine and the schematic of the test setup is presented in Figure 1. The engine with a specification in Table 2 was operated with constant load at 50% with a different speed of 2700, 3100 and 3500 rpm. The engine speeds are measured using a digital tachometer. Three different volume of n-butanol with 5ml, 10ml and 15 ml were blended with B20 diesel-palm oil methyl ester blends which are B20+Bu5, B20+Bu10 and B20+Bu15 are fuelled into the engine.
To ensure the accuracy and consistency of the measurement data the engine had been running approximately for ten minutes with diesel fuel after each test. Also, each test was repeated for 3 times in order to have a consistent and reliable measurement. The average values were used for drawing the graphs. Exhaust emissions data was by using a MRU Infrared Gas Analyzer to detect output of CO, CO2, HC, and NOx. The gas analyser has been calibrated by the company to assure the accuracy of the data collection.

Table 2. Engine specification.

| Model                | BENMA 5GF-ME                  |
|----------------------|-------------------------------|
| Engine Type          | Single cylinder, 4-stroke engine, air cooled |
| Fuel Tank Capacity   | 1.5 L                         |
| Fuel                 | Diesel                        |
| Displacement         | 418 cm$^3$                    |
| Starting System      | Recoil Start                  |
| Rated AC Power (Net) | 4.5 kW / 3600 rpm             |
| Max AC Power (Net)   | 5.0 kW / 3600 rpm             |
| Max Output           | 10 HP / 3600 rpm              |
| AC Output Voltage    | 240 V                         |
| Net Weight/Gross Weight (kg) | 100/104         |
| Dim (L x W x H)      | 727 x 495 x 597               |
| Lubrication oil      | SAE10W/30                     |
| Frequency            | 50 Hz                         |

3. Result and Discussion
The results and discussion are presented in this chapter based on the outcome of the experiment that has been conducted and by referring the literature, reviews, journal, internet and books to get a clear point of view on this study. Besides, the engine performance parameters that are evaluated are BSFC and BTE. For engine emissions parameters, CO2, CO, NOx, and HC emissions are evaluated. These parameters were compared between diesel fuels and four sample blended fuels. In addition, the engine was tested under three different speeds which are 2700, 3100 and 3500 rpm with a constant load of 50%. The results of the parameters of engine performance and emissions are plotted in bar chart.
3.1. Properties of fuel blends

3.1.1. Density of fuels

Figure 2 shows the graph of density comparison among tested fuel blends which are diesel (D100), B20, B20+Bu5, B20+Bu10 and B20+Bu15. Density is known as the mass per unit volume of a substance [21]. Previous study also state that the density is one of the fuel properties that affect the performance and emission of an engine [18]. From the graph, B20 shows the highest density value with increment of 4.01% (0.959 kg/m$^3$) compare to diesel fuel. However, the n-butanol fuel blend B20+Bu5 has the lowest density with reduction of 4.34% (0.8882 kg/m$^3$). The density of B20+Bu10 and B20+Bu15 increases as more n-butanol content is added into the fuel blends with increment of 0.01% (0.9229 kg/m$^3$) and 3.43% (0.9536 kg/m$^3$) respectively compare to baseline diesel (0.922 kg/m$^3$). When the density of fuel is higher than another, it indicates more mass of fuels with same amount of volume entering the combustion chamber, as new generation diesel injectors that supply fuel to the combustion chamber for power generation control the amount of fuel by volume rather than mass. The more fuel entering the cylinder resulting more emissions such as the increase of CO$\text{2}$ and NOx emission by biodiesel fuel [22]. It can be concluded that density have affect the efficiency of the combustion process in diesel engine.

3.1.2. Viscosity of fuels

The comparison of kinematic viscosity between diesel fuel, D100 and biodiesel-n-butanol fuel blends (B20, B20+Bu5, B20+Bu10 and B20+Bu15) are shown in figure 3. Kinematic viscosity is the ratio of

![Figure 2. Density of tested fuel blends](image-url)

![Figure 3. Kinematic viscosity of tested fuel blends](image-url)
dynamic viscosity to density of a substance. It is a crucial property which affects the fuel fluidity \[23\]. From the graph, B20 has the highest kinematic viscosity value compared to diesel (0.00362 m\(^2\)/s) with increment by 42.27\% (0.00515 m\(^2\)/s). Previous study also found that biodiesel has higher viscosity compared to diesel and n-butanol fuel blends \[8\],\[10\],\[24\]. For n-butanol blends, the kinematic viscosity decreased as the n-butanol content in the fuel blend increases. The average increment of kinematic viscosity values for B20+Bu5, B20+Bu10 and B20+Bu15 are 41.44\% (0.00512 m\(^2\)/s), 31.49\% (0.00476 m\(^2\)/s) and 20.17\% (0.00435) respectively compared with diesel fuel. The higher viscosity of B20 can lead to deterioration of spray properties and resulted in poor atomization in cylinder \[24\]. Higher viscosity and fuel density result in reduced evaporation due to larger fuel droplets that cannot be sufficiently atomized in the cylinder \[17\]. To overcome this problem, adding alcohol such as n-butanol into biodiesel can reduce the density and viscosity of the fuel blends due to its fuel characteristics which is agree by previous researchers \[8\],\[18\],\[24\]. Thus, it can be concluded that adding n-butanol into biodiesel fuel blends improves the kinematic viscosity of the fuel.

### 3.1.3. Calorific values of fuels

![Figure 4. Calorific values of tested fuel blends](image)

The figure 4 shows a graph of comparison of calorific values between diesel and other fuel blends. Calorific value is important parameter in determining the fuel properties. Calorific values can be defined as the amount of heat that a fuel produced when it is fully burnt and the combustion products are cooled to standard temperature and pressure (STP) \[25\],\[26\]. From the graph, diesel has the highest calorific value at 44.496 MJ/kg compared to biodiesel B20 and other n-butanol fuel blends. The percentage reduction of calorific value for B20, B20+Bu5, B20+Bu10 and B20+Bu15 compared to diesel are 11.19\% (39.515 MJ/kg), 11.61\% (39.328 MJ/kg), 12.10\% (39.114 MJ/kg) and 12.47\% (38.946 MJ/kg) respectively. From the results, it is found that the calorific value decreases as more alcohol content such as n-butanol is added into the fuel blends which also can be found in previous study \[12\], \[18\]. Both biodiesel and butanol have lower energy content than diesel fuel due to their oxygen content that will causes lead to increase in BSFC \[6\], \[18\], \[27\]. It can conclude that adding more alcohol into fuel blends can lowering the calorific value of the fuel blend which is agree by previous researcher \[14\], \[18\].

### 3.2. Engine Performance

#### 3.2.1. Brake Specific Fuel Consumption (BSFC)
Brake specific fuel consumption (BSFC) of fuel blends at different engine speeds are presented in Figure 5. It can be seen that BSFC values of B20 are higher on average by 17.24% than those of Diesel fuel. An increasing volume of n-butanol to B20 will further increase in BSFC values for all engine speed test and the average increments of BSFC compare to baseline Diesel fuel are 27.28%, 45.37% and 59.2% for B20+Bu5, B20+Bu10 and B20+Bu15 respectively. The highest BSFC values for the fuel blends at engine speed of 3500 rpm is B20+Bu15 which is 304 g/kW.hr, following B20+Bu10 (288 g/kW.hr), B20+Bu5 (262 g/kW.hr), B20 (241 g/kW.hr) and Diesel fuel which has the lowest of BSFC values (210 g/kW.hr) among the others. It is obvious that increasing the n-butanol volume will increased BSFC compared to Diesel fuel and B20. The finding is consistent with findings of past studies [10,11],[18] which both B20 and n-butanol have lower energy content than Diesel fuel, due to their oxygen content. The lower calorific value is the reason for the higher BSFC for the same power output, hence consumption energy per power is also increased which was consistent with the finding of İ. Örs et al. [18]. Furthermore, the ignition efficiency of n-butanol is lower compared to diesel. This lead to partial combustion of fuel and increase on the BSFC value for the fuel blends as stated by other researchers [8],[28].

3.2.2. Brake Thermal Efficiency (BTE)

Figure 5. BSFC of fuel blends at different engine speeds

Figure 6. BTE of fuel blends at different engine speeds
The result for brake thermal efficiency (BTE) of all test fuel under constant engine load at 50% and different engine speeds (2700rpm, 3100rpm and 3500rpm) are shown in Figure 6. It can be seen that BTE values of B20 are lower on average by 13.73% than those of Diesel fuel. This is due to higher viscosity and lower energy content of B20 reflects the findings of G. Goga et al. [8]. However, with increasing n-butanol volume to B20, BTE increased for all engine speed test compared to B20 but still lower by an average of 10.19%, 7.58% and 4.29% for B20+Bu5, B20+Bu10 and B20+Bu15 respectively compared to Diesel fuel. The BTE values of butanol fuel blends are slightly higher than B20 due to the increased of n-butanol fraction resulting increase in oxygen content in the fuel blends [4],[8],[10],[29]. Oxygen content of butanol promote in complete combustion during the diffusion combustion phase while the lower cetane number of the blends prolong the ignition delay, burning larger fraction of the fuel during the premixed mode, thus increase the temperature in the cylinder, resulting in increasing of BTE [4],[7]. However, the butanol blends have lower BTE compare to baseline diesel fuel because butanol has high latent heat of evaporation that reducing the combustion temperature in the cylinder that will lead to impartial combustion of fuel especially at high engine speed, thus reducing BTE [4],[8]. On the other hand, lower BTE is observed for ternary blends containing B20 and the overall viscosity and lower calorific value of the blend are the proposed to be the contributing factors for lower combustion efficiency [32].

3.3. Exhaust Emissions

3.3.1. Carbon Monoxide (CO) Emission

Changes in CO emission of all test fuel under constant engine load at 50% and different engine speeds (2700rpm, 3100rpm and 3500rpm) are shown in Figure 7. It can be observed that maximum CO emission value for all test fuel were obtained at 2700rpm which is due to lack of oxygen content in the air-mixture at lower engine speed, causing partial combustion to occur [8],[28]. The lowest CO emissions for all test fuel were obtained at 3100rpm. The use of biodiesel reduced the CO emission values compared to diesel at all engine speed tested with average CO emission reduction of 15.78% compared to diesel fuel. The reduction of CO emission is due to lower carbon contents and higher oxygen content of the biodiesel, thus lead to more complete combustion in the combustion chamber [8],[10],[18]. Higher oxygen particles presence in the fuel caused the carbon atoms to react with oxygen atoms to convert into CO2 gas as many as possible which led to complete combustion which was consistent with the finding of G. Goga et al. [8] and İ. Örs et al. [18]. In addition, the average reductions of CO emission for B20+Bu5, B20+Bu10, and B20+Bu15 compare to baseline diesel are 21.75%, 17.06% and 11.28% respectively. Similar results were obtained by İ. Örs et al. [18], who concluded that
by using biodiesel and n-butanol decreases CO emission due to presence additional oxygen in the additives improve the combustion process compared to diesel fuel. However, there are slight increases of CO emission as the number of n-butanol increased in the fuel blend due to high latent heat of vaporization of n-butanol. This cause the cooling effect in the combustion cylinder, reducing the cylinder temperature which lead to incomplete combustion, causes CO formation to occur [18], [29]. Although there are slight increase of CO emission at higher n-butanol blend, the results will not go any higher than baseline diesel [18].

### 3.3.2. Carbon Dioxide (CO2) Emission

The CO2 emission results for all test fuels under constant engine speed at 50% load with different engine speeds are shown in Figure 8. The minimum CO2 emissions value were observed at 2700rpm for all test fuels due to lack of oxygen content in the air-mixture at lower engine speed, causing partial combustion to occur [8],[27]. However, higher engine speed increases the engine volumetric performance and fluid mixing process which leads to more complete combustion consequently increase of CO2 emission value for all test fuel [30]. From the results, B20 has higher CO2 emission values

![Figure 8. CO2 emissions of fuel blends at different engine speeds](image)

Compared to diesel at all engine speed tested with average increase CO2 emission of 6.71% due to higher oxygen contents in biodiesel. The abundant of oxygen atoms in the fuel causes carbon atoms to fuse with adequate of oxygen atoms to form into CO2 gas, thus lead to more complete combustion in the combustion chamber [18]. From the result, increasing n-butanol volume to B20 blends decrease CO2 emission value for all engine speed condition. The average increase of CO2 emission for B20+Bu5 is 2.12 %, whereas the average reduction of B20+Bu10, and B20+Bu15 compare to baseline diesel are 3.35 % and 5.75 % respectively. Previous studies also reported that increase the n-butanol proportion in the diesel-biodiesel blend also reduced the CO2 emission [15],[31]. The reduction of CO2 emission for n-butanol fuel blends is due to high latent heat of vaporization of n-butanol which lead to the cooling effect in the combustion cylinder, reducing the cylinder temperature causing the combustion to be incomplete. Thus, lead to CO formation to occur and reducing CO2 emission for the fuel blends [18, 29]. The chilling effect of n-butanol causing ineffective oxidation of CO to CO2 has also been documented by previous researchers [29]. Also, this could be explained by the balance between CO and CO2 formation during the combustion process. The formation of CO2 decreased as the emission of CO increase [18]. Hence, the CO2 emission of n-butanol fuel blend decrease as the content of n-butanol in the fuel blend increases.
3.3.3. Hydrocarbon (HC) Emission

Figure 9. HC emissions of fuel blends at different engine speeds

Figure 9 shows the result of hydrocarbons (HC) emission of the internal combustion engine fuelled with diesel (D100), B20, B20+Bu5, B20+Bu10, and B20+Bu15 under the engine condition constant engine load of 50% with different engine speeds of 2700, 3100 and 3500 rpm. The lowest HC emission values of diesel, B20 and n-butanol blends can be observed at lowest engine speed which is 2700rpm while the maximum HC emission values occurred at 3500rpm for all test fuel. The average reductions of HC emission for B20, B20+Bu5, B20+Bu10, and B20+Bu15 compare to baseline diesel fuel are 22.29%, 18.51%, 15.68% and 12.13% respectively. The highest reduction of B20 is due to the higher oxygen content in biodiesel improved combustion and increase of the exhaust gas temperature [10],[14],[18]. Besides, compared to diesel fuel, biodiesel with higher cetane number promote premixed combustion by shorten the ignition delay period hence reducing the HC emissions [8],[14],[18],[29]. The lower density and viscosity values of n-butanol causing the combustion to be improved better than diesel fuel, thus reducing the HC emission value [18],[23]. However, increasing the volume of n-butanol in the fuel blends slightly increase the HC emissions compared to B20. The low cetane number of n-butanol causing longer ignition delay period which consume more time for the evaporation of the fuel blend in combustion, thus lead partial combustion to occur [8],[11]. Besides, higher heat of evaporation of n-butanol causes the fuel blends evaporating at slower rate, thus increase the HC emission for the n-butanol blend [11]. Therefore, the increasing of n-butanol content in the fuel blends lead to increase in HC emission compare to biodiesel B20.
3.3.4. Nitrogen Oxides (NOx) emissions

Figure 10. NOx emissions of fuel blends at different engine speeds

Formation of NOx emission substantially depends on the temperature of the combustion flame. Generally, low cetane number will affect ignition delay by increasing the end of combustion temperature for the quantity of premixed combustion. Figure 10 illustrates NOx emission results for all test fuels at a constant half load 50% and at different engine speed (2700, 3100, 3500rpm). The maximum NOx values were obtained for all test fuels at 3500rpm engine speed, while the minimum values were recorded at 2700rpm. The average increases in NOx emission value for B20 and B20+Bu5 fuels compared to diesel fuel were 8.97% and 3.34% respectively. In contrast, the average reduction in emission values of B20+Bu10 and B20+Bu15 fuel blends were 3.34% and 7.10% respectively. From the result, B20 blend has been found to increase NOx emissions as the oxygen content of B20 is higher than that of diesel fuel which improves more combustion, thus increasing the combustion temperature in the cylinder [8], [11], [18]. Previous study also reported that the high oxygen particles presence in the biodiesel caused the nitrogen atoms to react with adequate amount of oxygen to form into NOx gas in the cylinder [18]. As the cylinder temperature increase due to improved combustion, the nitrogen atoms react with oxygen atoms at higher rate, generates more formation of NOx gas, hence increase the NOx emission for biodiesel fuels [12]. In contrast, increasing n-butanol in the blends has positively decreased NOx emissions. Higher heat of evaporation and lower calorific value of butanol induces the cooling effect in the cylinder and reduces NOx emissions as stated by previous researchers [8], [11], [18]. Also, further reduction on NOx emission for all different engine speeds has been recorded when higher butanol concentration added on the blends. This is due to lower cetane number and longer ignition delay reduces in cylinder temperature during the premixed combustion phase. Hence, minimizing the formation of NOx emission [8], [18].

4. Conclusion

In this study, the effect of diesel-biodiesel blend with fuel additives has been explored as an alternative fuel for future. The performance of the engine and the exhaust emissions in a single cylinder compression ignition engine was fully evaluated at constant engine load of 50% and three different engine speed fuelled with diesel, biodiesel B20 and the n-butanol – biodiesel fuel blends. The n-butanol fuel blends were compared with diesel as a base fuel. From the result, it can be concluded that biodiesel B20 has a disadvantage on engine performance such as higher BSFC and lower BTE compared to diesel fuel. Oppositely, B20 has an advantage on exhaust emission such as lower CO and HC but slightly higher for CO2 and NOx. However, addition of n-butanol to biodiesel significantly decreases some essential thermo-physical parameters such as density, viscosity, and calorific value, in addition to
enhancing the properties of combustion. Furthermore, n-butanol shows a better result on engine performance for BTE and exhaust emission for CO₂ and NOx when blends with B20. This is due to higher oxygen and latent heat of vaporization of n-butanol promoting better combustion hence increasing BTE on engine performance and reducing CO₂ and NOx on exhaust emission. In overall, the addition of 5ml n-butanol to biodiesel B20-diesel fuel blends show the most significance result for the engine performance and exhaust emissions at all test condition.

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