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Experimental Investigation on a Fuel Efficiency and its Emission of CI Engine Using Higher Blend Biodiesel

Nik Ahmad Daniel Nik Robidin[1], Shaiful Fadzil Zainal Abidin[1]*

[1] *Centre of Automotive and Powertrain Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia*

*Corresponding Author: sfadzil@uthm.edu.my
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Abstract

Biodiesel fuel reduces greenhouse gas emissions and dependence on fossil fuels, making it an environmentally friendly choice for powering vehicles and industrial engines. Determining the optimal biodiesel blending ratio is vital for maximizing engine performance and minimizing environmental impact, ensuring a balanced approach to sustainable energy use. This study aims to evaluate the fuel consumption and emission of a compressed ignition engine with various blending ratios. The research outputs will examine its brake-specific fuel consumption (BSFC) and emission level. The methodology consists of a set of precise experiments carried out on a testing engine. The experiments involve systematically altering the blend ratios of biodiesel and analysing their impact on the efficiency of combustion and emissions. The engine's fuel consumption and exhaust emissions is measured extensively under different operating conditions, allowing for a comprehensive evaluation. The experiment reveals when the percentage of biodiesel blends increases, fuel efficiency slightly decreases as the fuel's overall energy content lowered and engine performance decreased. This suggests that biodiesel gives somewhat less energy for a given amount. This finding is valuable and will contribute to the development of sustainable and efficient fuel strategies. The pressing need for eco-friendly transportation solutions motivates this investigation to offer viable alternatives in renewable energy sources and cleaner propulsion technologies.

1. Introduction

The global automobile industry still has a long way to go in mitigating the damaging consequences of burning conventional fossil fuels on the environment. Consequently, the significance of sustainable and alternative energy sources for internal combustion engines is increasing. Biodiesel derived from renewable resources is becoming more and more popular as a fuel alternative for compression ignition (CI) engines since it emits less greenhouse gases and has the potential to replace traditional diesel fuel[1].

It has been shown that adding biodiesel to diesel fuel alters the engine's emissions and combustion characteristics. The study suggests that higher blend biodiesel, or biodiesel with a higher percentage in the fuel combination, may offer additional environmental benefits[2]. To fully understand the complex interactions between higher blend biodiesel and the combustion processes in CI engines, more experimental research is needed. Understanding these interplays is crucial for enhancing engine efficiency and ensuring compliance to more stricter emission standards.

Numerous studies have examined blends with varying percentages of biodiesel in relation to the usage of biodiesel in CI engines. These studies have provided insight into the features of emissions, engine power output, and combustion efficiency. The specific effects of higher blend biodiesel on fuel atomization, combustion stability, and overall engine performance still require investigation.

Even though the literature that is now available provides useful information on the use of biodiesel in CI engines, the effects and optimal operating conditions of greater mix biodiesel remain uncertain. This research attempts to bridge this gap by conducting a thorough and experimental examination of the brake specific fuel consumption BSFC and emissions profiles of a CI engine using a higher proportion of biodiesel.

2. Equipment and Method

The materials and techniques utilized for this project are thoroughly explained in this subsection. It contains details about the software and hardware, block diagrams, and process flows for the project. A system flow diagram's figure illustrates the relationships between each stage and gives a general idea of how everything works together. This serves as a guide for comprehending the project's design. The components of software and hardware in this section are required to achieve the desired outcomes.

2.1 Equipment

The main goal of this experimental study is to look into higher mix biodiesel's fuel consumption and emissions. through the use of a Yanmar L70N single-cylinder diesel engine coupled to the i3 DAQ System Software and a specially designed burette-style fuel measurement device to determine the fuel usage. The BOSCH BEA 060 Emission Analyzer is used to get emission data for exhaust gas emissions analysis. The principal elements and software utilized in this undertaking are i3 DAQ System Software, custom burette type fuel measuring device, BOSCH BEA060 Emission Analyser, palm oil biodiesel (B10, B20, B30, B40) and Yanmar L70N single cylinder diesel engine with specification as Table 1.

Table 1 *Yanmar L70N specification*

Model			**L70N**
Type			4 stroke, vertical cylinder, air-cooled diesel engine
No. of cylinders			1
Bore x stroke		mm	ø78 x 60
Displacement		Liter	0.32
Continuous rated output	Engine speed	rpm	3600
	Output	kW	4.3
Maximum Rated Output	Engine speed	rpm	3600
	Output	kW	4.8
High idling		rpm	3800±30
Engine weight (dry)	Electric starter	kg	43
	Recoil start	kg	38
Cooling system			Force air-cooling by flywheel fan
Lubricating system			Forced lubricating system
Starting system			Electric start/ recoil start
Dimension	Overall length (L)	mm	395
	Overall width (W)	mm	488
	Overall height (H)	mm	472
Lubricating system	Dipstick Upper limit	Liter	1.1
	Dipstick lower limit	Liter	0.7
Fuel tank capacity		Liter	3.3

2.2 Method

Fig. 1 shows flowchart was used to help the experiment proceed as planned. The baseline testing is conducted, and the experiment is set up. Results of the baseline testing are examined and contrasted with information from earlier studies. The collection of biodiesel fuel was started once the data trend appeared to be similar to other research papers. Every fuel blend being tested, and the data gathered from the results being analysed and summarised.

Palm oil biodiesel fuel with different blend will be used as fuel and being analysed their BSFC and emission. Each of the fuel blend were blend manually based on the calculated value. Yanmar L70N engine run by using different biodiesel blend. BOSCH BEA 060 were used to analysed the exhaust gases released during testing of each fuel. i3 DAQ System plays a crucial role as it will control the throttle percentage. It will help maintain the engine rpm without needing to manually control the throttle by hand which will make more error.

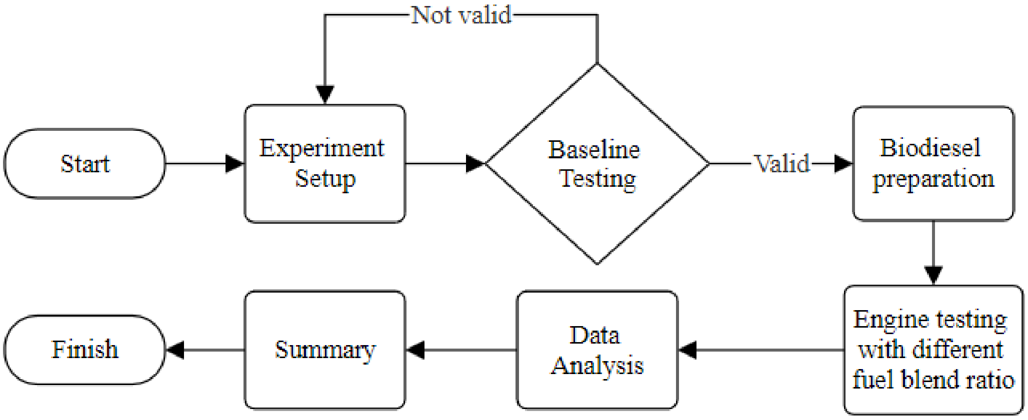

Fig.1 *Flowchart of the experimental investigation*

2.3 Experiment Setup

Fuel consumption for each fuel blend were measured of running engine at 2500rpm and 3000rpm with each test was set for 10% load until 50% load with 10% increment. The exhaust gases were analysed using BOSCH BEA 060 emission analyser. 2000rpm, 2500rpm and 3000rpm with 0% load used for emission analysis of each fuel blends.

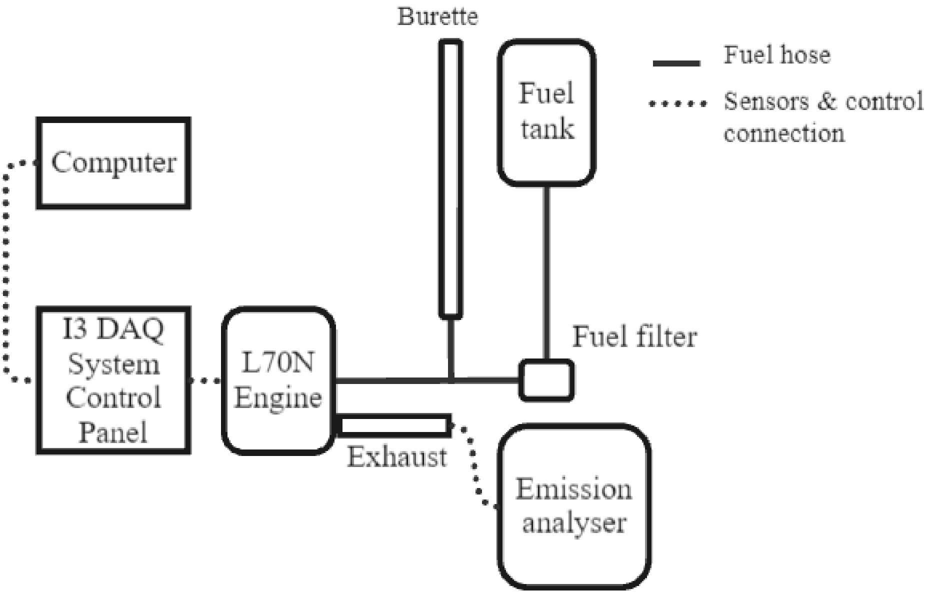

Fig.2 *Experimental setup diagram*

Table 2 *Experiment matrix*

No.	Fuel	rpm	Load %				
1.	B10	2500 3000	10	20	30	40	50
2.	B20	2500 3000	10	20	30	40	50
3.	B30	2500 3000	10	20	30	40	50
4.	B40	2500	10	20	30	40	50

3000

2.4 Biodiesel Preparation

The biodiesel blend used in this experimental investigation was B10, B20, B30 and B40. The only fuels available are B10 biodiesel fuel and B100 palm oil. The formula is used to combine B10 and B100 fuel to create B20, B30, and B40 palm oil biodiesel fuel. The formula was first used to calculate how much B10 and B100 gasoline would be needed to make B20 fuel. The precise blend of B10 and B100 gasoline was ensured by measuring the quantity using a measurement cup, pouring it into a bucket, and swirled for around ten minutes.

B20 Fuel Calculation:
A= B100
B= B0
X= B100 quantity needed to make it became B20

$$\frac{A+X}{9B}=\frac{2A}{8B}$$

$$X=\frac{5}{4}$$

Multiple by 0.2 thus the B10 fuel needed is 2L and B100 fuel should be use is 0.2×5/4 = 0.25l. Thus, total B20 fuel Produced is 2.25l.

B30 Fuel Calculation:
Y = B100 quantity needed to make it became B3

$$\frac{A+Y}{9B}=\frac{3A}{7B}$$

$$X=\frac{20}{7}$$

Multiple by 0.2 thus the B10 fuel needed is 2l and B100 fuel should be use is 0.2×20/7 = 0.57l. Thus, total B30 fuel Produced is 2.57l.

B40 Fuel Calculation:
Z= B100 quantity needed to make it became B40

$$\frac{A+Z}{9B}=\frac{4A}{6B}$$

$$X=5$$

Multiple by 0.2 thus the B10 fuel needed is 2l and B100 fuel should be use is 0.2×5 = 1l. Thus, total B40 fuel Produced is 3l.

Table 3 *Fuel blend quantity*

Biodiesel Types	Blend Quantity, l		Total Quantity, l
	Diesel Fuel (B10)	Palm Oil B100	
B20	2	0.25	2.25
B30	3	0.57	2.57
B40	2	1	3

3. Result and analysis

This part is devoted to the analysis and discussion of data gathered from the experiments that were carried out in relation to the project's objectives. Four different blends of palm oil biodiesel fuel were tested.

3.1 Result for brake specific fuel consumption (BSFC)

The brake-specific fuel consumption graph for the B10, B20, B30, and B40 at 2500 rpm versus load is displayed in Fig.3. The greatest BSFC value during a 10% (2.7N) load is 624 g/kWh for B40, followed by 592, 562, and 555 g/kWh for B30, B20, and B10. This indicates that B40 is less efficient because it uses the most fuel when operating at a 2.7N load. At 20% (5.4N) load, the BSFC's location altered. The lowest BSFC value was 361 g/kWh for B20, whereas the highest values were 376, 380, and 391 g/kWh for B40, B10, and B30. This indicates that at 20% (5.4N) load, B40 operates at its highest efficient level. But during the 30% (8.1N) load, it changed once more, with B10 being the most efficient at 307 g/kWh, followed by B30, B20, and B40 at (317, 328, and 336) g/kWh. B10 remains the most efficient load at 40% (10.8N) with a value of 264 g/kWh, followed by B20, B30, and B40 with values of 271 g/kWh, 296 g/kWh, and 317 g/kWh. The 53 g/kWh difference between the least and greatest BSFC values on a 30% load is rather noteworthy. At last, during a 50% (13.5N) load, the fuel blends B10 and B20, which have the same least BSFC, are valued at (243 and 261) g/kWh, followed by B30 and B20. Biodiesel generally has a lower energy content per unit volume compared to conventional because of its high viscosity, biodiesel made from domestic natural sources has a lower energy content than diesel fuel made from petroleum diesel fuel[3]. As the biodiesel content increases (from B10 to B40), the overall energy content of the fuel mixture decreases, leading to higher fuel consumption to achieve the same power output. The combustion properties of biodiesel can differ from those of conventional diesel. Higher biodiesel mixes may impact engine performance and emission characteristics due to slower combustion rates and poorer atomization[4], resulting in less efficient energy conversion and higher BSFC.

Table 4 *BSFC of B10, B20, B30 and B40 biodiesel fuel at 2500rpm*

Load	2500rpm BSFC, g/kWh			
N	B10	B20	B30	B40
2.7	555	562	592	624
5.4	380	361	391	376
8.1	307	328	317	336
10.8	264	271	296	317
13.5	234	234	243	261

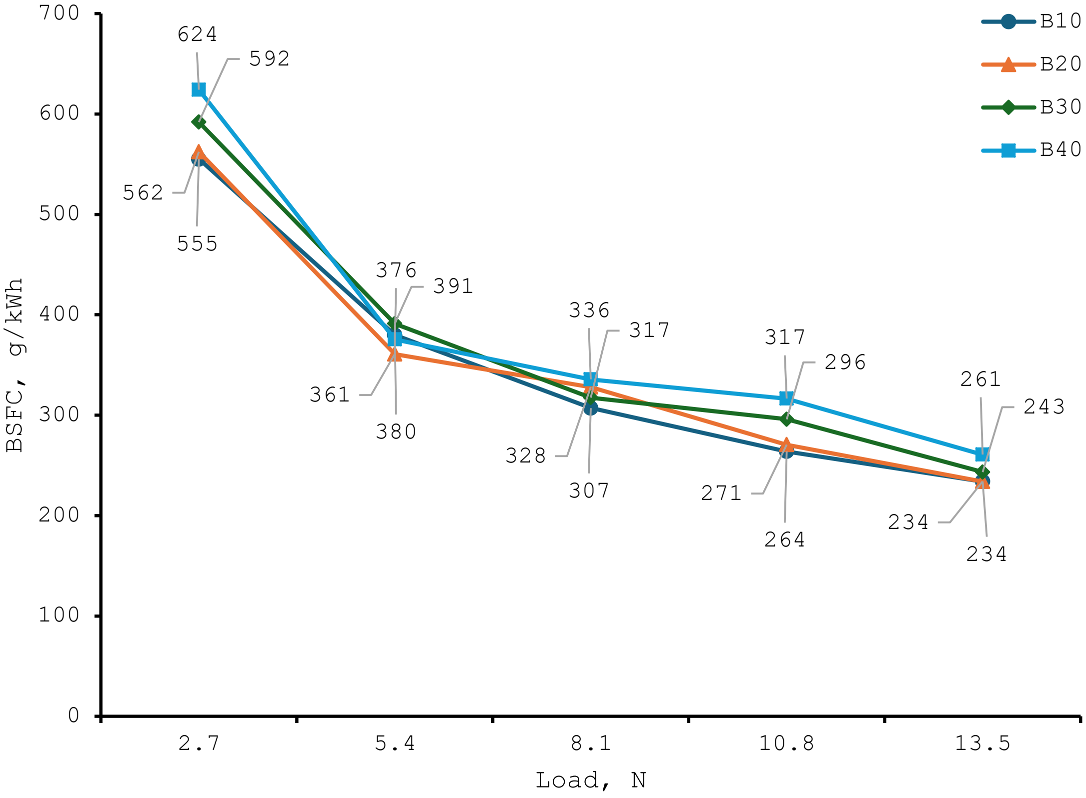

Fig.3 *BSFC against load for B10, B20, B30 and B40 at 2500rpm*

Fig.4 shows the fuel consumption curve for the B10, B20, B30, and B40 specifically for brakes at 3000 rpm versus load. For a 10% (2.7N) load, B30 has the lowest BSFC value at 579 g/kWh, followed by B20, B10, and B40 at 601, 612, and 671 g/kWh. The fact that B40 consumes the most gasoline when running at a 2.7N load suggests that it is less efficient. At 20% (5.4N) load, the location of the BSFC changed. B30 had the lowest BSFC value of 373 g/kWh, whereas B10, B20, and B40 had the highest values of 410, 401, and 401 g/kWh. At 30% (8.1N) load, B30 has the highest efficiency at 320 g/kWh, followed by B10, B20, and B40 at 325, 325, and 342 g/kWh. With a value of 282 g/kWh at 40% (10.8N) load, B10 is the most efficient, followed by B20, B30, and B40, whose values are (301, 315, and 318) g/kWh. Finally, at a 50% (13.5N) load, the fuel blends B10, B20, B30, and B40 are the most efficient, with the lowest BSFC of 241 g/kWh. Higher blends of biodiesel (such as B40) have higher viscosity compared to lower blends[5]. This can affect the fuel injection process, causing less efficient fuel spray patterns and incomplete combustion, thus reducing overall efficiency[6]. Besides that, The oxygen concentration of palm oil biodiesel is approximately 10–11% greater than that of regular diesel fuel[7], which can affect the air-fuel ratio and combustion efficiency. While some oxygen can promote better combustion, too much oxygen (from higher biodiesel content) can lead to leaner combustion mixtures, potentially causing higher fuel consumption[8]. Also need to highlight the fluctuation occurred during the 5.4N, 8.1N and 10.8N occurred may be due to the experimental running conditions. The break time during each run makes the engine temperatures varies thus make the engine character slightly different[9].

Table 5 *BSFC of B10, B20, B30 and B40 biodiesel fuel at 3000rpm*

Load	3000rpm BSFC, g/kWh			
N	B10	B20	B30	B40
2.7	612	601	579	671
5.4	410	401	373	401
8.1	325	325	320	342
10.8	282	301	315	318
13.5	241	249	261	284

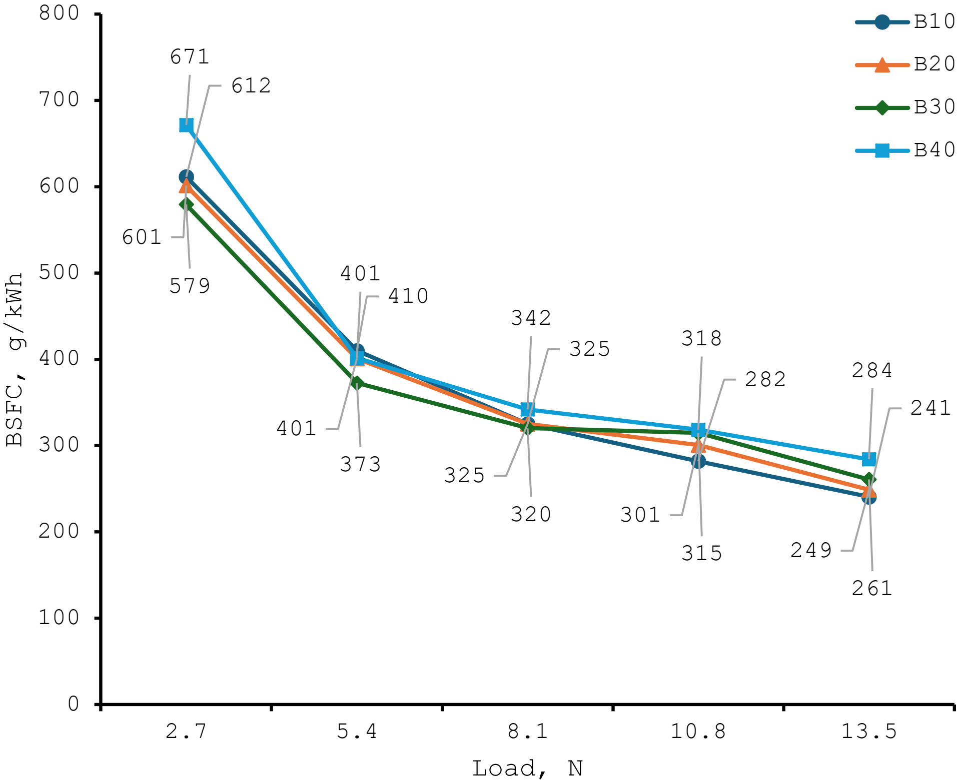

Fig.4 *BSFC against load for B10, B20, B30 and B40 at 3000rpm*

3.3 Emission analysis

The exhaust gases produce during testing were analysed for its emission using BOSCH emission analyser BEA060. Each blends were analysed for its emission at 2000rpm, 2500rpm and 3000rpm with 0% load. B20, B30 and B40 emission were compared its percentage different of B10. Carbon dioxide emissions are the outflow of unburned gases that have a high oxidation content, no colour, and no smell. According to Table 6, less carbon monoxide is released when a higher blend of biodiesel is utilised. Additionally, Table 7 illustrates how carbon dioxide emissions have decreased, although there are still a number of points where emissions have increased. This is in line with other studies that showed reduced emissions of carbon dioxide and carbon monoxide [10]. Offering advantages over fossil fuels in terms of efficiency, economy, and the environment, palm biodiesel has the potential to reduce world emissions and promote sustainable development [11].

Table 6 *Carbon monoxide (CO) percentage difference compared to the baseline B10*

Engine Speed rpm	Carbon Monoxide %		
	B20	B30	B40
2000	-30.36	-30.36	-28.57
2500	-23.81	-21.43	-33.33
3000	-15.91	-20.45	-36.36

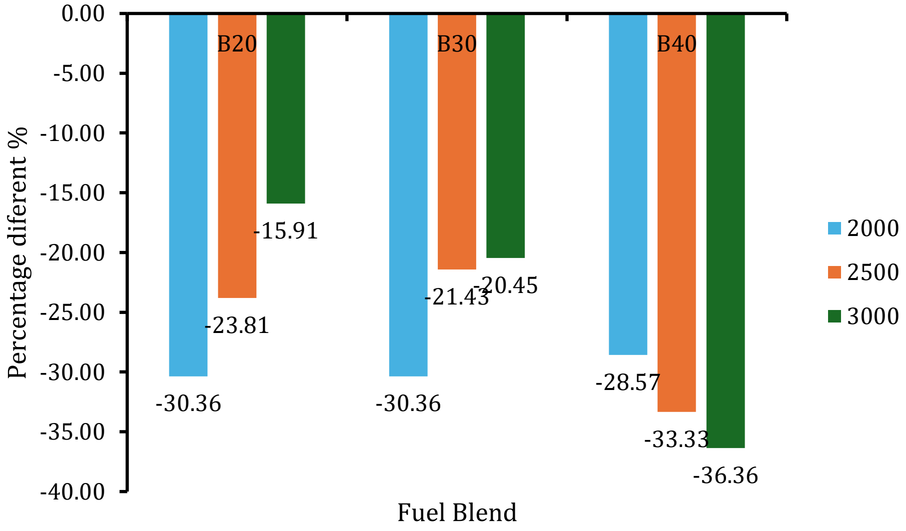

Fig.5 *Graph of CO percentage difference compared to B10*

Table 7 *Carbon dioxides (CO_2) percentage different compared to the baseline B10*

Engine Speed rpm	Carbon Dioxides %		
	B20	B30	B40
2000	-13.19	-3.30	-1.10
2500	-1.14	2.27	-4.55
3000	8.13	-2.44	0.81

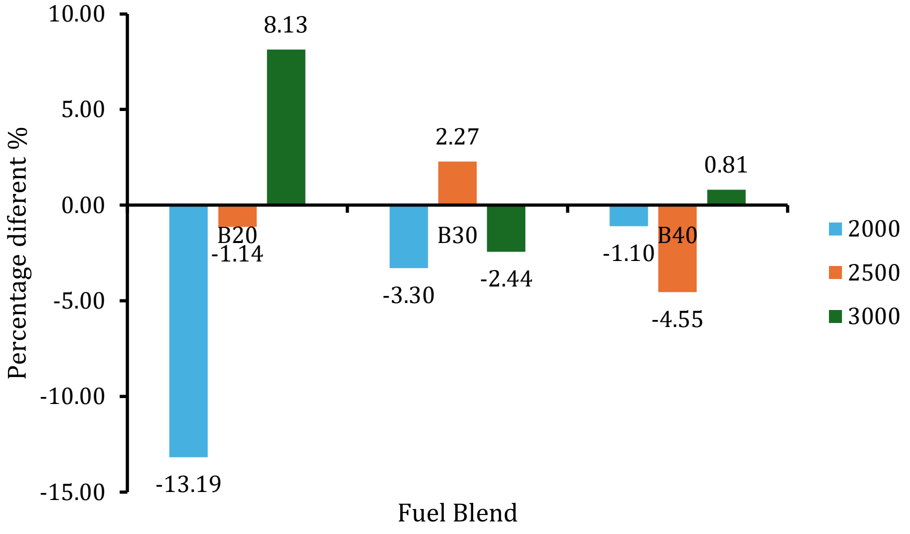

Fig.6 *Graph of CO_2 percentage difference compared to B10*

Diesel engines that emit brownish exhaust in higher temperature zones over 800 °C are known for their NOx emissions. From mild upper respiratory irritation to chronic respiratory and heart illness, lung cancer, and acute respiratory infections, NO gases can have both acute and long-term consequences on human health[12]. Based on the Table 8, NO is decreased for B20 and B40 however on B30 the NO is increased. This is different from the result of similar experiment conducted by [13]. The main factors contributing to increased NO generation in diesel engines are greater inlet temperature, injected mass, advanced injection time, and in-cylinder combustion temperature which is why during B30 NO increased [14]. The reason for the development of NO in diesel engines is the uneven distribution of temperatures regions with temperatures between 1500k and 1900K are more conducive to the formation of soot thus this happened may be cause the engine is too hot during running B30 [15].

Table 8 *Nitrogen oxide (NO) percentage different compared to the baseline B10*

Engine Speed rpm	Nitrogen Oxide %		
	B20	B30	B40
2000	-50.00	20.00	-20.00
2500	-30.00	0.00	-30.00
3000	-20.00	20.00	0.00

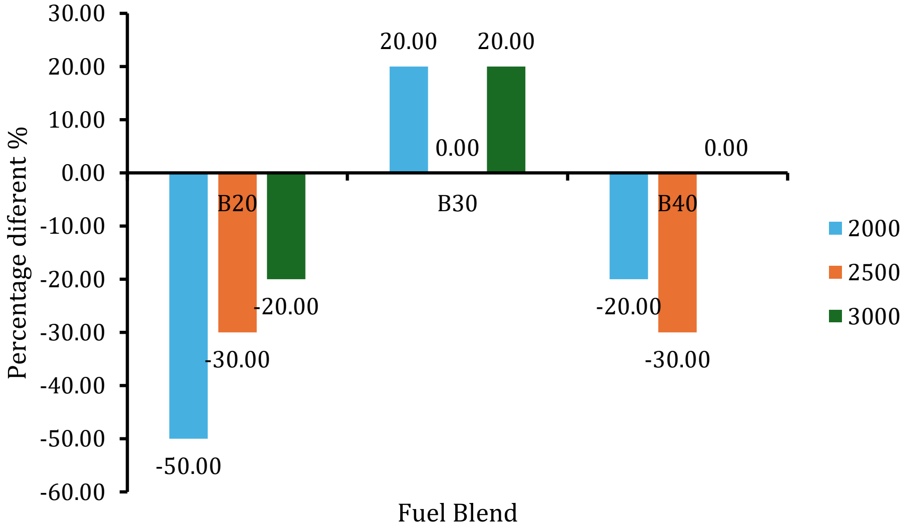

Fig.7 *Graph of NO percentage difference compared to B10*

"Hydrocarbon emissions" is the phrase used to describe the precisely quantified creation of linear emissions caused by a lack of oxygen. Incomplete combustion brought on by an advanced injection time combined with an overly rich or low fuel mixture is what causes unburned hydrogen emissions in diesel. On Table 9 shows the percentage of HC produce were lowered for every increasing biodiesel blends. This experiment's outcome is consistent with earlier studies that stated higher mixes of biodiesel derived from palm oil (B10, B20, and B30) efficiently reduce hydrocarbon (HC) emissions in diesel engines to a very low level [16][17].

Table 9 *Hydrocarbon (HC) percentage different compared to the baseline B10*

Engine Speed	Hydrocarbon %		
rpm	B20	B30	B40
2000	-34.62	-30.77	-34.62
2500	-22.73	-22.73	-22.73
3000	-17.39	-21.74	-26.09

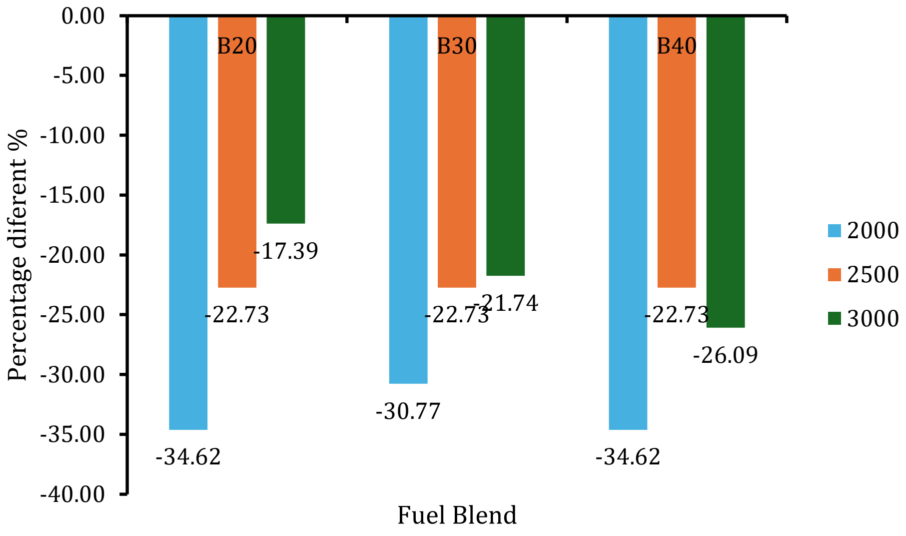

Fig.8 *Graph of HC percentage difference compared to B10*

4 Conclusion and recommendation

This experimental study was conducted to evaluate the fuel consumption of a compressed ignition (CI) engine fuelled by varying higher blend biodiesel B10, B20, B30 and B40. Investigate the correlations between biodiesel blend ratios and emissions levels. Comparing which biodiesel blend ratios give the best brake specific fuel consumption (BSFC). In these experimental studies different blend of biodiesel fuel was used that is B10, B20, B30 and B40 to investigate the changes of BSFC value and emission emitted. All test has been conducted and be concluded as follows:

1. Higher biodiesel blend levels can affect engine performance depending on several variables, such as type of biodiesel, the engine technology, and the mix amount.
2. In general, biodiesel has less energy than regular diesel fuel. This indicates that biodiesel offers somewhat less energy for a given amount. thus, the power and fuel efficiency may somewhat decline as the amount of biodiesel blend increases since the fuel's overall energy content may drop and the engine performance will drop.
3. Higher blend palm oil biodiesel reduces emissions of CO, CO_2, NO, and HC, but its acceptability is still debatable because, according to B30 emissions analysis, it produces higher emissions of CO_2. Thus, this emissions analysis still needs to further investigate in a more detailed experiment for example using the Ni-CAS system.

Based on the experimental data gathered, the results show that the study's goals were achieved. However, there are a few suggestions that can be done to get better statistics and information.

1. Make a better experiment matrix for example using the same rpm and load for both BSFC and emission test. Thus, the data can be related to each other to get a better view of the experiment result.
2. This experiment only conducted with a one time run only after the experiment setup is done. Thus, to get a better accepted data this experiment needs to run for several time to get the average data get a good trendline data.
3. Make a further investigate in a more detailed experiment, for example using the National Instrument Combustion Analysis System Software (CAS) system.
4. Using a sensor for fuel flow data can lessen error during testing.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The study's conceptualization and design, data collecting, analysis and interpretation of the findings, and paper preparation are all acknowledged to be entirely within the author's domain.

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