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ORIGINAL ARTICLE

Evaluation of a Single Cylinder Compression Ignition Engines Operated with Castor Biodiesel Blends

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Abstract

Diesel engines have proved useful in transportation and agriculture. These engines have contributed to the development of decentralized energy networks for rural electrification. Concerns over the long-term supply of petroleum diesel and strict environmental regulations, have necessitated the rapid exploration of renewable alternatives to diesel fuel to address these issues. The impact of castor oil biodiesel blends on diesel engine performance was investigated in this study. The trial experiment was carried out on a single-cylinder compression ignition engine. The tests were conducted at an engine-rated speed of 850 rpm under various loading conditions (0 - 6 kW) to determine engine performance. Physicochemical parameters of castor biodiesel and its blends were analysed and compared to diesel fuel. The calorific value of prepared castor biodiesel blends ranged from 41.80 MJ.kg-1 to 39.50 MJ.kg-1 for blends of B5 to B50, whereas pure diesel had a calorific value of 42.00 MJ.kg-1. In addition, the kinematic viscosity of the blends of biodiesel examined increased from 4.50 to 6.50 cSt for the same range of fuel. The findings show that lower biodiesel blends (5 – 25%) are acceptable within ASTM standards. This make it to be a viable alternative fuel in near future.

***Keywords**: Biodiesel blend, Castor biodiesel, Diesel fuel, Engine Performance, Fuel characteristic, Single cylinder engine*

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1. Introduction

Access to clean, modern, and sustainable energy is a major challenge facing Nigeria as a nation because energy is key to any socioeconomic development and poverty elimination. Today, about 60 to 70% of the Nigerian populace does not have access to constant electricity (Oyedepo, 2012). There is no doubt that the current energy crisis will remain until the government diversifies the energy sources required for both the home and industrial sectors and implements new affordable and sustainable technologies. This help to transform waste into useful products and reduce energy-generating costs. Variations in crude oil prices on the global market, as well as increased concern about the environment and the effects of greenhouse gas emissions on the world's climate, are making the notion of utilizing both edible and non-edible fat and its derivatives as fuel more widely accepted (Busari and Olaoye, 2020).

Several studies investigated the potential of utilising vegetable oil as a diesel engine replacement (Mahmudul *et al*., 2017; Bello and Daniel 2015). According to Shrestha *et al.* (2005), biodiesels and biodiesel blends may be utilized in their raw form to fuel any existing internal combustion engine without substantial changes. Furthermore, according to Alptekin and Canakci (2009), biodiesel fuel has both physical and chemical characteristics similar to petroleum fuel. The use of non-edible oil such as castor oil in place of diesel fuel might be good for harnessing and converting discarded seeds in the wild, which are largely considered weeds, into a valuable commodity.

Most of the studies done on engine performance using various biodiesel blends have reported a loss of brake power, torque decrease, and higher brake-specific fuel consumption (BSFC) (Liaquat *et al*., 2012). Also, Liaquat *et al*., (2012) also added that reduction in hydrocarbon (HC), carbon monoxide (CO), sulphur dioxide (SO_2), polycyclic aromatic hydrocarbons (PAH), nitric polycyclic aromatic hydrocarbons (nPAH), and particulate matter (PM) emissions were noticed when biofuel was used to powered diesel engines. Another study reported that a 25% jatropha methyl ester blend with diesel has shown the best performance, but pure jatropha methyl ester had reflected the worse brake thermal efficiency due to its high kinematic viscosity when compared to diesel fuel (Rao *et al*., 2007). More so, previous research found that under different loading situations, the braking thermal efficiency of jatropha biodiesel and its blends was greater than that of petroleum diesel oil (Rao *et al*., 2007).

Furthermore, Carraretto *et al*., (2004) studied a six-cylinder direct injection engine and found that as the amount of biodiesel in the mix increased the engine power and torque decreased across all specified engine speeds. Ghobadian *et al*., (2009) on the other hand, found a drop in power output and torque with greater brake specific fuel consumption while using waste cooking oil biodiesel compared to conventional diesel fuel, as well as reduced CO and HC emissions. According to Panwa *et al*., (2010), vegetable oils may be used to power compression ignition engines, both directly and in combination with conventional diesel. The main disadvantage of using vegetable oils as a fuel is their high viscosity, which hurts engine combustion (Busari and Olaoye 2017). Nigeria's heavy reliance on petroleum fuels in the transport and power generation sectors necessitates the exploration of sustainable alternatives to foster economic development (Muhammad *et al*., 2013). In the transportation and agricultural sector, where diesel fuels were used for powering heavy vehicles and equipment Remarkably, conventional diesel engines are readily adapting to these alternative biofuels without extensive modifications as reported

This study determined the acceptability of utilizing biodiesel made from non-edible oil (castor oil) and investigated the effect of castor biodiesel addition (5 to 50% in volume) on single cylinder stationary diesel engine.

2. Materials and Methods

2.1 Sample preparation

A wild castor seed of about 50 kg was collected, dried, and expelled using a combined roaster expeller. The oil expelled (25%) was converted to biodiesel using an alkaline transesterification process with potassium hydroxide as a catalyst and methanol as a solvent. Catalyst (2%) was dissolved in methanol for the experiment, and the mixture was added to the measured castor oil. The prepared mixture was then agitated at the constant temperature (65°C) and time (1.80 h) to prevent side reaction, catalyst activation and optimal reaction rate. The reactant was put into a clear container and allowed to settle for nearly 6 hours at ambient temperature. Glycerin was left at the bottom of the container while methyl ester was on top, and biodiesel was poured into another vessel that had been cleansed and filtered after the mixture had settled. To eliminate liquid remnants, the collected fuel was heated for 10 minutes at 110°C. Thereafter, the recovered fuel was allowed to cool at ambient temperature. The finished product (biodiesel fuel) was mixed with diesel fuel in the following proportions: 5%, 10%, 15%, 20%, 25%, and 50%, respectively, while 100% biodiesel was used as a control. Biodiesel blends has been used to test engine performance and performance indices were used to determine relevant parameters.

2.2 Physico-chemical properties of castor biodiesel blends

The methods reported by Busari and Olaoye (2020) and Busari *et al*., (2020) with some modifications were used for the determination of the physico-chemical properties.

2.3 Determination of specific gravity and density

The ASTM D1298 standard was employed for measuring the density and specific gravity of the prepared castor biodiesel and its blends as reported by Busari *et al.,* (2020). A Density Meter (Rudolph Research Analytical: DDM 2911 Automatic Density Meter), known for its precision (accuracy to 0.00005 g.cm^{-3}) and manufactured in the United States of America, was utilized for this purpose.

2.4 Determination of flash point

The flash point was determined in accordance with ASTM-D93 standards following a specific procedure. About 70 ml of the oil sample was transferred to a test cup equipped with a thermocouple sensor. Subsequently, the sample was subjected to heating and agitation at intervals of 5–6°C per minute and 90–120 rpm, respectively. An ignition source was periodically applied to the test cup, commencing from 23 to 28°C below the anticipated flash point. Agitation ceased only upon the detection of a distinct flash. The recorded flash point was identified as the lowest corrected temperature under a barometric pressure of 101.3 kPa (ASTM, 2008). The flash point is a critical parameter in evaluating biodiesel's safety profile. Its relatively high flash point enhances biodiesel's appeal as a safer and environmentally friendlier alternative to fossil fuels in various applications. high flash point indicates that the biodiesel is less likely to produce flammable vapors at ambient temperatures, reducing the risk of accidental ignition during storage and handling (Knothe, 2005)

2.5 Determination of kinematic viscosity

The viscosity of castor oil and biodiesel were determined according to the ASTM D445 standard procedure at a temperature of 40°C using a calibrated Viscometer (NDJ – IB Rotational Viscometer; Shanghai Chamgji). The sample was poured into the beaker and placed directly onto the spindle of the machine, which was then activated to initiate the measurement. The displaced readings were noted and recorded.

2.6 Determination of calorific value/ heat of combustion

The calorific value was determined using a conventional bomb calorimeter (IKA Calorimeter, System C200 Basic Control) following the guidelines outlined in ASTM D240. A specimen of known mass was combusted under controlled conditions. Oxygen from a gas cylinder, pressurized between 20 – 35 Atm., was introduced to initiate combustion. The outcome was then observed and recorded on the bomb calorimeter's screen display (Busari *et al.,* 2020)

2.7 Experimental Set-up

The purpose of the experimental set-up is to systematically evaluate the performance, combustion, and emission characteristics of a single-cylinder compression ignition engine when operated with castor biodiesel blends. The set-up is designed to assess critical engine parameters, such as brake thermal efficiency, specific fuel consumption, and exhaust emissions, under various operating conditions. These parameters help determine the viability of castor biodiesel blends as an alternative fuel for diesel engines and stationary diesel engine were commonly used engines for post-harvest processing in Nigeria. The experiment was set up in the Farm Power and Machinery Laboratory of the Food and Agricultural Engineering Department, Kwara State University Malete. A JUMBO stationary diesel engine was used for the performance analysis of the castor biodiesel and its blends. The complete experimental set-up utilised for the study with a load plane is presented in Figure 1, and the key technical specifications of the engine are listed in Table 1. The engine was connected to a dynamometer (Model DG-1 Mega-Tech. Corporation) to monitor engine torque, and an alternator was placed in front of the stationary diesel engine to change/vary the loads. The load bank was made up of thirty pieces of 200 W bulbs that were divided into six groups, each group with five bulbs, and controlled by a switch. The loads ranged between 1 kW to 6 kW. Table 2 shows the specifications of the alternator that was used. Experiments were done for 30 minutes with pure diesel and different biodiesel blends. A portable tachometer was used to measure the engine's speed in RPM, and a calibrated 100 ml burette was used to monitor the fuel consumed by the engine.

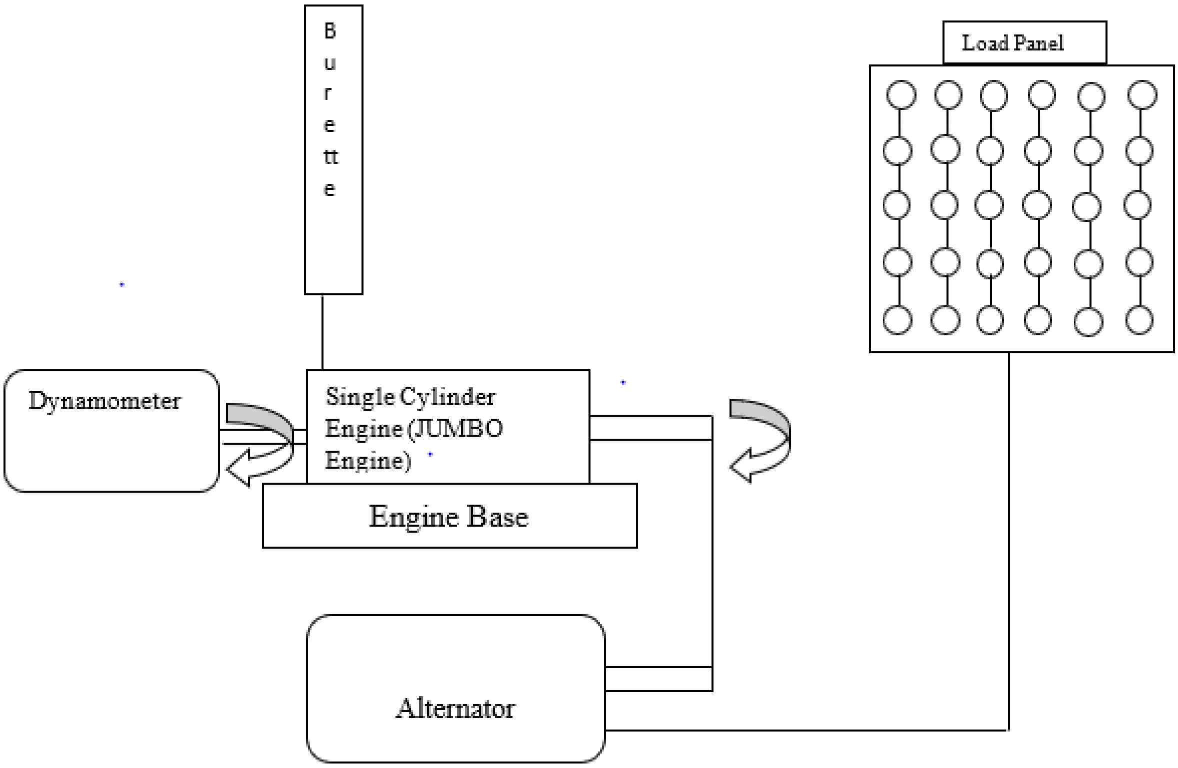

Figure 1: Complete Experimental Set-up

Table 1: Engine technical specification

No.	Item	Technical Datasa
01	Model	JUMBO stationary diesel engine
02	Type	Four-stroke, vertical, and cold starting enclosed
03	Power	8hp /6 kW
04	Bore (mm) x Stroke (mm)	114.3× 139.7
05	Rotation	Clockwise
06	Combustion principle	Compression ignition
07	Capacity (cm^3)	1432.71
08	Engine speed (rpm)	850
09	Fly Wheel Dia. (mm)	590

10	Flywheel width (mm)	90
11	No. of cylinder	One
12	Cooling system	Water
13	Starting	Manual with a cranking handle
14	Bearing	taper roller bearings
15	Engine lubricating system	splash type

Table 2: Alternator specifications

No.	Particular	Specifications
01	Model	Delmax
02	Output	7.5 kVa
03	Voltage	230
04	Speed	1500 rpm
05	Frequency	50 Hz
06	Type of Cooling	Force feed cooled

2.8 Experimental Procedure

To obtain baseline data, the research was conducted using conventional diesel. Hence before collecting any data, the engine was stabilized. Experiments were then done using biodiesel blends and raw castor biodiesel for comparison.

2.9 Fuel consumption measurement

A calibrated burette of 100 ml was employed and filled with fuel, well above the top indicated mark, and the stopcock was locked. Thereafter, the cock was opened to enable the passage of fuel to the engine. In each batch of the experiment, the engine was run for 30 minutes, and the fuel consumed was noted for record purposes.

3. Biodiesel Evaluation Performance Indices

3.1 Determination of brake power

The engine output was calculated using Equation 1, as given by Ramana *et al*., (2015) and Srivastava *et al*., (2008).

$$PB = \frac{2\pi NT}{60\times1000} kW \quad (1)$$

where;

N = speed, rpm,

T = torque, Nm.

3.2 Mass of fuel consumed (MFC)

The fuel consumption rate was calculated using Equation 2 as reported by Ramana *et al*. (2015) and Srivastava *et al.,* (2008)

$$MFC = \frac{X\times\rho\times3600}{1000\times T} kgh^{-1} \quad (2)$$

where,

X - burette reading in cc,

ρ - fuel density in $g.cc^{-1}$, and

T - time taken in seconds.

3.3 Determination of brake specific fuel consumption (BSFC).

The BSFC is an important parameter to analyse the performance of the engine and fuel efficiency. The BSFC was computed using Equation 3 as stated by Ramana *et al*., (2015) and Srivastava *et al*., (2008)

$$SCF = \frac{MFC}{PB} \quad (3)$$

where,
SCF - brake specific fuel consumption, kg.kW^{-1}h^{1},
BP - brake power, kW;
MFC - fuel consumption rate, kg. s^{-1}

3.4 Determination of brake thermal efficiency

The brake thermal efficiency was computed using Equation 4 as reported by Srivastava *et al*., (2008)

$$\eta_{bth} = \frac{PB}{Hg \times MFC} \times 100 \quad (4)$$

where,

η_{bth} −Brake thermal efficiency, %

IP - Indicated power in kW,

MFC - Mass of fuel consumed in kg.h^{-1}, and

CV - Calorific value of diesel = 42500 kJ. kg^{-1}

4. Results and Discussion

4.1 Characteristic and properties castor biodiesel blends

The properties of various blends were examined at the Industrial Chemistry Laboratory, Kwara State University Malete. The calorific value of convectional diesel fuel was found to be 42,000 kJ. kg^{-1}. as reported by Acharya *et al*., (2016) and castor biodiesel determined was 38,470 kJ. kg^{-1}. Calorific values for various blends were 41, 800, 41,620, 41,410, 41,230, 40, 200, 39, 500 kJ. kg^{-1} for B5, B10, B15, B20, B25, and B50, respectively which is relatively comparable to diesel fuel. Castor biodiesel has 8.40% lower energy content than diesel fuel (42,000 kJ. kg^{-1}.). The low calorific value of castor biodiesel may be due to the oxygen content of castor biodiesel, and this will increase specific fuel consumption of biodiesel as compared to diesel fuel. Hence, brake power produced using castor biodiesel is low compared to diesel as a result of the lower calorific value of castor biodiesel. The result is similar to the findings of Bello and Daniel (2015) who reported a calorific value of 39800 kJ.kg^{-1} for groundnut biodiesel. Also, Xue *et al.,* (2011) noted that the calorific value of fuels is a crucial indicator of their ability to release energy for work. As a result, the lower calorific value of biodiesel is related to a reduction in engine power, which is widely agreed upon by literature that states that the engine power decreases while using biodiesel from vegetable oil (Bello and Daniel 2015; Xue *et al.,* 2011).

Kinematic viscosity is another important parameter that plays a key role when castor biodiesel is used to power the engine. The kinematic viscosity of pure Castor biodiesel was 10.9 cSt as compared to conventional diesel measured (2.3 cSt) while the Kinematic viscosity of different blends measured were 6.5, 4.79, 4.76, 4.73, 4.64, and 4.5 cSt for B50, B25, B20, B10, and B5, respectively. Castor biodiesel and its blends have higher kinematic viscosity than diesel fuel. From the obtained result, B5, B10, B15, B20 and B25 has a comparable viscosity to conventional diesel (according to ASTM and EN standards). This implies higher viscosity will result in a larger droplet diameter of Castor biodiesel in the combustion chamber. Therefore, castor biodiesel and its blends require higher injection pressure than diesel. However, according to some report studies, increased viscosity causes power losses because it reduces combustion efficiency due to poor fuel injection atomization (Utlu and Kocak, 2008; Aydin and Bayindir, 2010).

Density of castor biodiesel was measured to be 840 g.cm^{-3} whereas diesel has a density of 0.82 g.cm^{-3}. Due to the higher density of castor biodiesel, specific fuel consumption will be more than that of diesel fuel because of lower calorific value. Therefore, more fuel will be required to compensate low calorific value of the vegetable oil. The result obtained for castor biodiesel is close to the previous work carried out on the same seeds by Asmare and Gabbiye (2014) whose result was 920 g.cm^{-3}. A similar trend was observed by Raheman and Ghadge (2007), who discovered that when crude mahua oil was converted to biodiesel, the density of the oil was lowered by about 9%. The densities were found to grow linearly as the biodiesel content in the blends increased.

Table 3 also shows the values of flash point of castor biodiesel and various blends. The flash point of diesel fuel measured 53°C, which is lower compared to 280°C of the castor biodiesel. With the higher flash point of castor biodiesel, it is comparatively safer to transport and store castor biodiesel than diesel.

Table 3: Physicochemical properties of raw castor biodiesel, biodiesel blends, and mineral diesel

Sample	B100	B50	B25	B20	B15	B10	B5	Mineral diesel Acharya *et al.*, (2016)
Density at 20°C, ($g.cm^{-3}$)	0.9536	0.9088	0.8805	0.8758	0.8720	0.8698	0.8654	0.824
Specific gravity	0.9554	0.9104	0.8821	0.8773	0.8735	0.8714	0.8669	-
pH	7.0	6.5	6.5	6.4	6.4	6	5.5	-
Flashpoint (°C)	280	130	115	112	110	105	102	53
Kinematic viscosity, mm^2s^{-1}	10.9	6.5	4.79	4.76	4.73	4.64	4.5	2.3
Calorific value, kJ. kg^{-1}	38,470	39,500	40,200	41,230	41,410	41,620	41,800	42,000

4.2 Engine Performance

In this research, engine performance was examined in terms of Engine speed, brake power (BP), brake-specific fuel consumption (BSFC), and brake thermal efficiency.

4.2.1 Engine speed

The engine speed was 830 rpm with no load when using diesel fuel as a baseline, but when using biodiesel blends, the engine speed dropped to 800 rpm at B5 and B10 for the same loading conditions. The speed continued to reduce as the engine load increased from 1 to 6 kW. Figure 2 depicts the fluctuation in engine speed as the biodiesel content increases and the engine is loaded up to maximum capacity (6 kW). Reported studies on biodiesel derived from canola, rapeseed, soybean, and beef tallow oil have come up with similar results (Olaoye and Busari 2017). According to Nabi *et al.*, (2009), the usage of castor biodiesel resulted in a decrease in engine speed. For groundnut ester, Oniya and Bamgboye (2013) found that as load increases up to 75 percent load, the engine speed continues to drop, after which it remains constant for additional load increases. As stated by Nabi *et al.*, (2009), the low calorific value, higher kinematic viscosity, poor spray properties, poor air-fuel combination, and low volatility of castor biodiesel resulted in a decrease in engine speed.

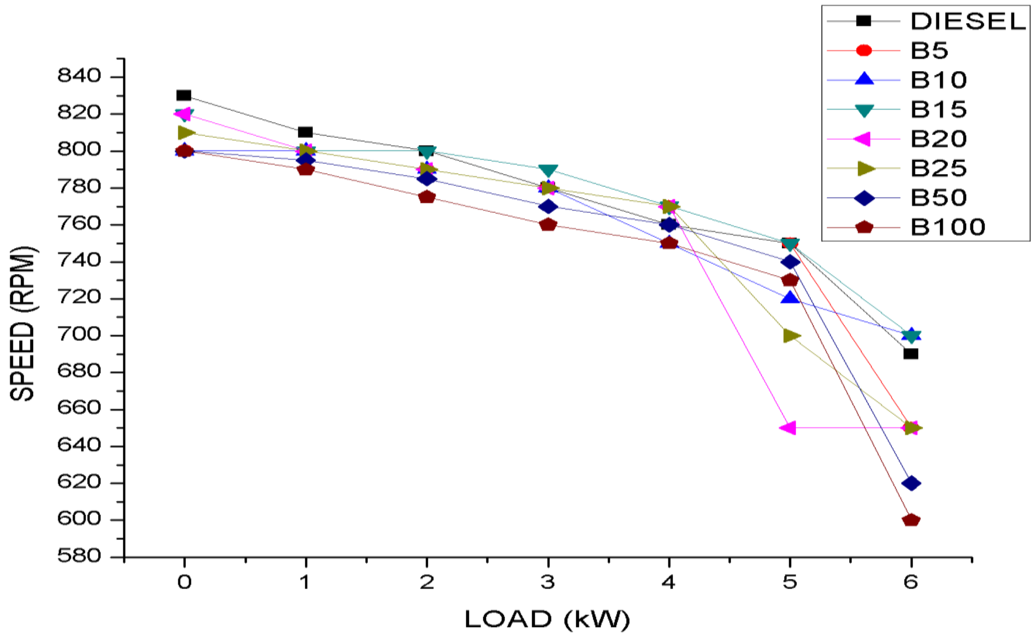

Figure 2: Speed variation for different biodiesel blends versus Load

4.2.2 Engine torque

Figure 3 shows the engine torque generated under various loading conditions for all biodiesel blends and diesel fuel. The torque curves for all blends and diesel fuels exhibited similar patterns and they decreased as the blend's concentration increased. Nedayali and Shirneshan (2016) stated that the values for the torque tend to decrease by increasing the biodiesel concentration in the fuel mixture for B80 and B100. These decreases are understandable since the heat content of the fuel blend decreases with the increasing amount of biodiesel compared to that of diesel fuel.

Because of the high viscosity, poor heating, and partial combustion of the engine, while utilizing biodiesel, this declining torque figure is considered normal for compression ignition engines as (Mohsin *et al*., 2014). The findings contradict the work of Ani *et al*. (2012), who found a small increase in maximum torque for B10 when compared to diesel. In addition, Altiparmak *et al.,* (2007) found that using a blend with 70% tall oil (extracted from softwood) biodiesel resulted in a 6.1% gain in maximum torque. The enhanced engine torque was attributable to the higher cetane number of biodiesels.

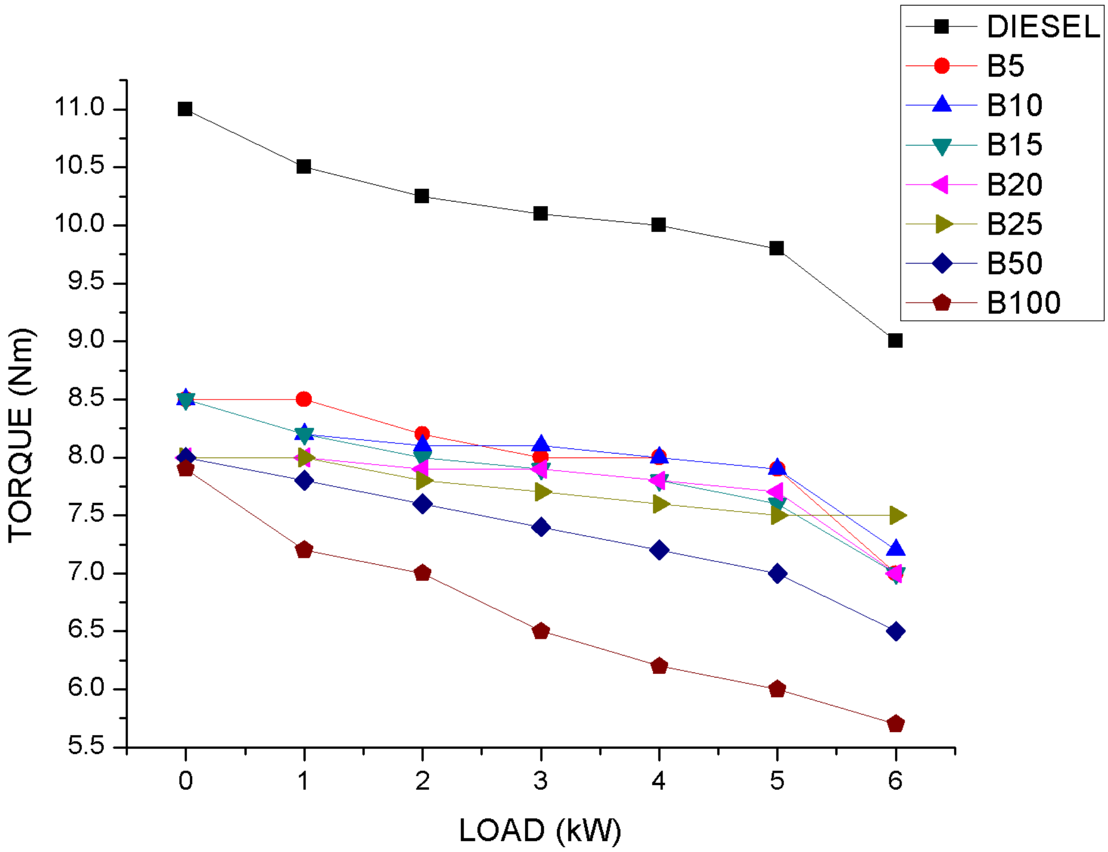

Figure 3: Torque of different biodiesel blends versus load

4.2.3 Brake-specific fuel consumption of the engine (BSFC)

Figure 4 shows changes in the specific fuel consumption with increasing biodiesel content on engine performance up to maximum load. The variations in BSFC follow the same pattern for all biodiesel blends. This is due the calorific value of biodiesel which is lower than conventional diesel. The BSFC values increase with increasing biodiesel concentrations in the blends under consideration. As a result, more fuel biodiesel will be required to compensate for poor calorific value of biodiesel. According to Nedayali and Shirneshan (2016), if biodiesel or its blends are used to power engines, the BSFC will increase owing to the reduced power produced due to the lower energy content fuel. However, as noted by Eze and Ejilah (2010), the greater BSFC of castor biodiesel blends in the experiment might be explained by low calorific value, higher viscosity, and specific gravity of biodiesel blends, implying higher fuel consumption per unit of power produced due to low combustion efficiency. In addition, Oniya and Bamigboye (2014) state that the BSFC at any loading condition was found to increase with a higher proportion of loofah ethyl ester in the blend. This may be due to the lower heat content of loofah ethyl ester. This agreed with the result obtained by Saravanan *et al*., (2007) who reported that BSFC developed by a diesel engine fuelled by blends of rice bran oil with Automotive Gas Oil (AGO) increased with an increase in the percentage of rice bran oil in the blends.

This research was similar to the findings reported by Zheng *et al*., (2008), who found a 23 percent increase in specific fuel consumption while using biodiesel in an engine. Another factor that may be responsible for the increase in methyl ester-specific fuel consumption is a shift in combustion time owing to higher cetane number of biodiesels as reported by Buyukkaya (2010). In a different setting, Sahoo *et al.,* (2007) found no difference between diesel fuel and biodiesel in their investigation. In contrast assertions, Reyes and Sepulveda (2006) found that methyl ester had a lower specific fuel consumption than standard diesel.

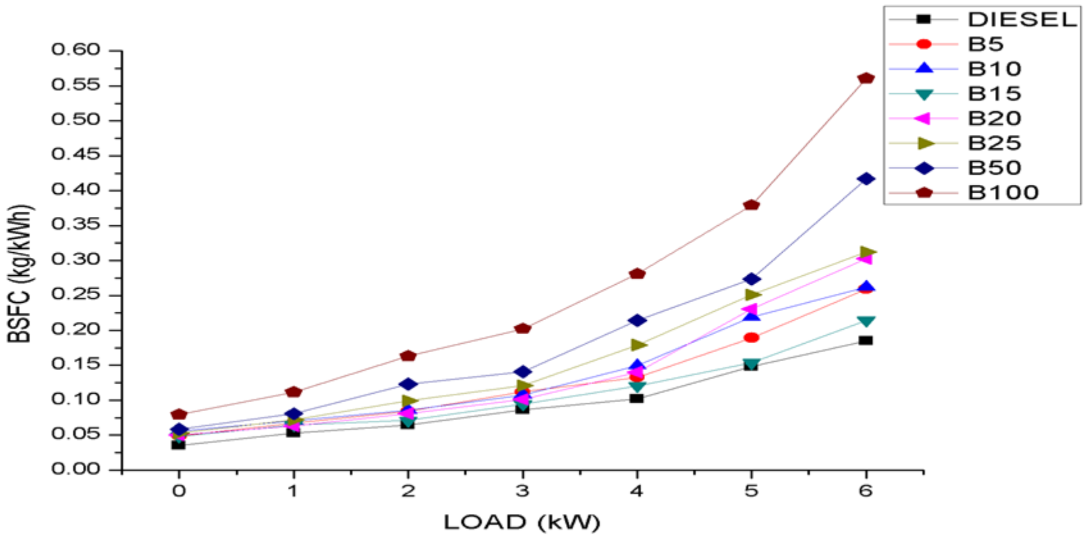

Figure 4: Brake specific fuel consumption variation for different biodiesel blends versus Load.

4.2.4 Brake thermal efficiency (BTE)

In all experiments, the BTE was reduced as the applied load increased. The full load BTE for B5 was 9.23%, which was higher than that of the convectional diesel fuel which stood at 7.79%. Hence, the same trend was observed for B10, B15, B20 and B25. But the case was different for B50 and B100 at full load, where BTE of 6.07 % and 4.64 % were recorded respectively, B5 – B25 yield better thermal efficiency as compared to B50 and B100 at full load. This initial thermal efficiency of the engine was improved as biodiesel concentration increased in the blends. This may be as a result of additional lubricity provided for the engine by biodiesel and the molecules in methyl ester contain a small amount of oxygen that participates actively in the combustion process (Pali *et al*., 2013). The thermal efficiency trend for B50 and B100 was in the reverse order, as concentration of biodiesel increase in the blends. The lower BTE found for B50 and B100 might be related to a low calorific value of blends and an increase in fuel consumption rate as reported by Nabi *et al*., (2009). The result obtained for BTE was similar to research carried out by Raheman and Ghadge (2008) who stated that there was a decrease in BTE with an increase in the proportion of fuel from vegetable oil blends with diesel fuel at all compression ratios and injection timings using a Ricardo E6 engine powered with Mahua biodiesel. Low calorific value, greater kinematic viscosity, poor spray properties, and low volatility all contributed to a loss in thermal efficiency with biodiesel (Nabi *et al*., 2009). In addition, low BTE might be caused by a delay in biodiesel ignition to combustion initiation before the piston reaches the top dead center, resulting in a reduction in engine efficiency and heat loss (Rao *et al*., 2007). Sahoo *et al*., (2009) and Raheman and Phadatare (2004) on the other hand, reported the reverse. Figure 5 depicts the influence of different biodiesel mixes on brake thermal efficiency under various loading circumstances.

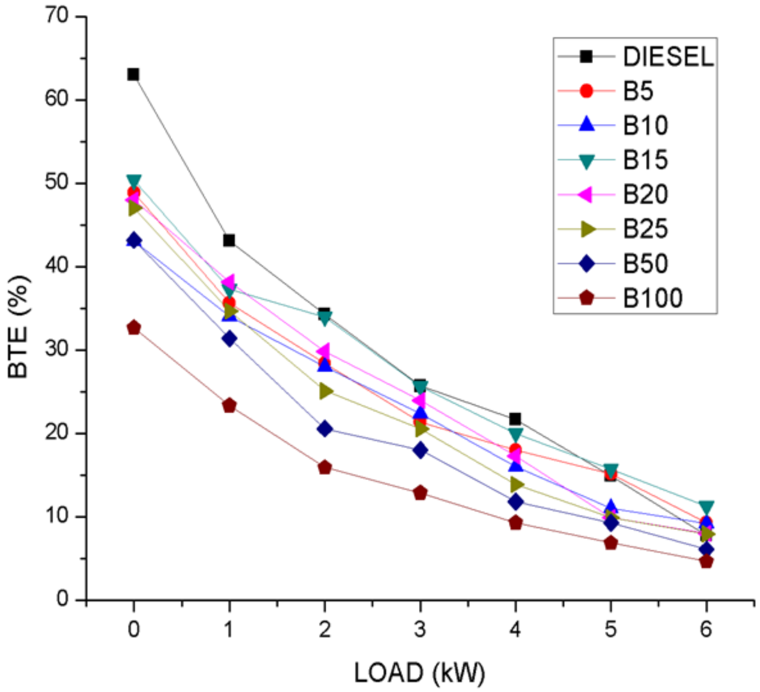

Figure 5: Brake thermal efficiency variation for different biodiesel blends versus Load

4.2.5 Brake power

Brake power for biodiesel and all blends' biodiesels were calculated using performance indices and compared with standard diesel fuel. For all fuels subjected to the test, the power reduced as the biodiesel concentration and load increases. As shown in Figure 6, the brake power for the diesel was higher when compared with castor biodiesel. This is due to the higher calorific value of the conventional fuel. The engine power decreases as the concentration of biodiesel increases. This may be due to the higher density, bulk modulus, and viscosity of vegetable oil-based fuels (Sharma *et al*., 2014). According to Sharma *et al*., (2014), biodiesel with a high density increases the mass of injection into the combustion chamber, whereas high viscosity lowers fuel leakage. On the other hand, Sharma *et al*., (2014) claimed that no significant difference in engine power between biodiesel and diesel. The explanation they gave was that fuels are delivered on a volumetric basis and that a higher biodiesel density means that more biodiesels would be supplied to compensate for the lower calorific value. The result obtained is like the findings of Wan Ghazali *et al*., (2015), who found that biodiesel blends had somewhat lower brake power than pure diesel. This means that the higher the concentration of biodiesel in the blends, the lower the power generated by the engine under investigation. In addition, Aydin and Bayindir (2010) emphasised that engine power was similarly reduced when methyl ester was used as a fuel for an internal compression engine.

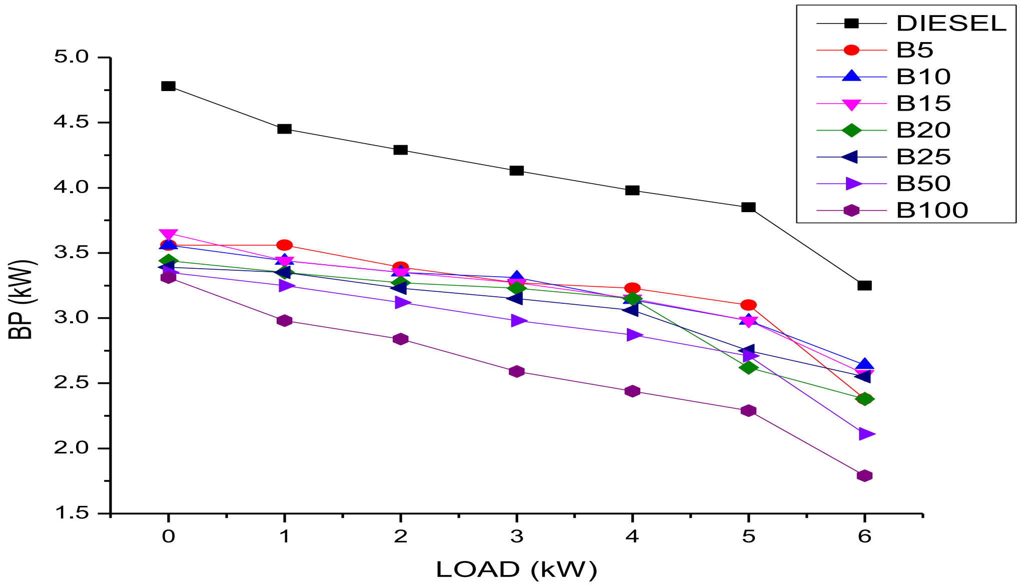

Figure 6: Brake power variation for different biodiesel blends versus Load

4.2.6 Brake Mean Effective Pressure (BMEP)

Figure 7 depicts the variance in BMEP as a function of engine loading conditions for various biodiesel blends. As the load increases, BMEP drops, as shown in Figure 8. The BMEP of standard diesel was greater than the BMEP of all blends under all loading conditions. As a result, the viscosity and volatility of the fuel are important factors in the atomization rate and enhancement of air-fuel mixing formation. The BMEP was impacted by the high viscosity and low volatility of castor biodiesel and its blends. The average BMEP for B5, B10, B15, B20, B25, B50, and B100 were determined to be 70.25, 70.13, 68.86, 68.01, 67.75, 64.44, and 58.24 kPa, respectively. The result implied that when the biodiesel content increases, the BMEP decreases. The results were similar to those obtained by Buyukkaya (2010), who tested a six-cylinder, four-stroke, turbocharged direct injection diesel engine using plain rapeseed oil and its mixes at 2000 rpm under full load and reported that with the addition of rapeseed oil to the blends, the peak cylinder pressure dropped. Other studies reported similar outcomes (Senthil *et al*.,2005; Canakci *et al*., 2009; Devan and Mahalakshmi,2009). Pressure decrease was explained as the effects of biodiesel viscosity on fuel spray, as well as reduced air entrainment and fuel/air mixing rates.

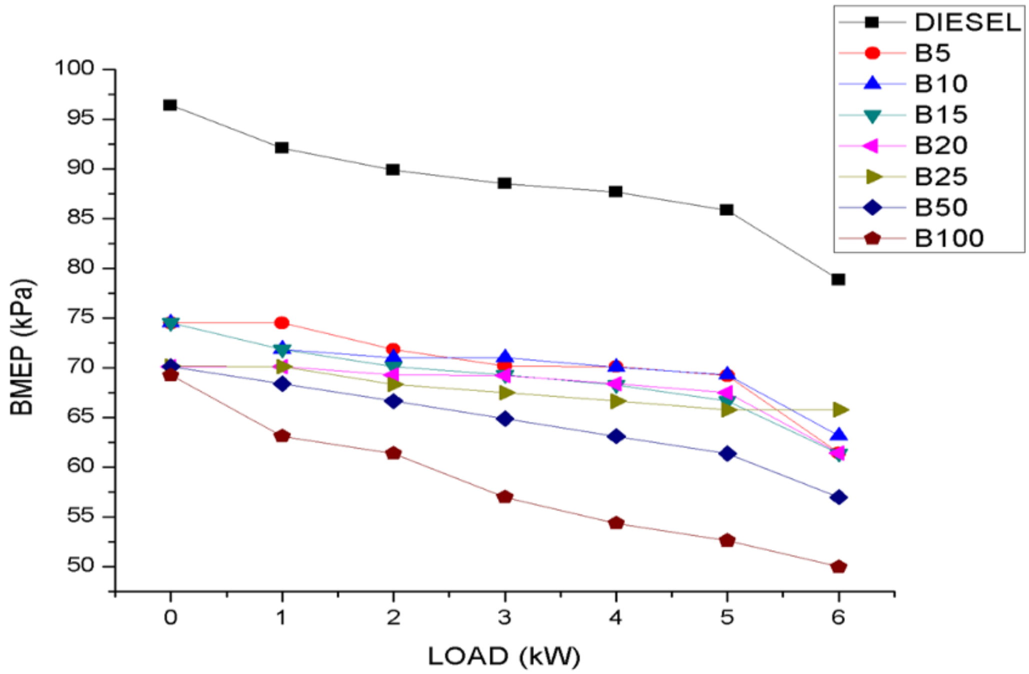

Figure 7: Brake Mean Effective Pressure of Different Biodiesel Blends versus Load

5. Conclusions

The research focused on the production of biodiesel from castor oil, biodiesel characterization, and performance testing on a single-cylinder engine using various biodiesel blends at varying loads. Except for B50 and B100, the fuel characteristics of castor biodiesel and its blends, were determined to be identical to conventional diesel fuel and mostly within ASTM requirements. The short-term performance of a diesel engine running on promising castor biodiesel revealed a minor loss in power output (brake power), as well as an increase in brake-specific fuel consumption. The torque, which decreased as the concentration of castor biodiesel increased, followed a similar pattern. This will allow farmers to generate fuel that can be used to power agricultural equipment without the need for conventional diesel. The low brake thermal efficiency might be related to the castor biodiesel's low volatility, high viscosity, and density, which impacts mixture formation and hence leads to sluggish combustion. Also, further engine endurance testing may be necessary to determine the effect of biodiesel on engine parts after extended use, as well as the mechanism of wear that may occur when castor biodiesel is used.

Conflicts of interest: The authors have no conflicts of interest regarding this publication.

5. References

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