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ORIGINAL RESEARCH ARTICLE

POTENTIALS OF UTILIZING BIODIESEL FROM COTTON SEED OIL BLEND WITH DIESEL AS AN ALTERNATIVE TO DIESEL FUEL IN NIGERIA

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ABSTRACT

The depletion of fossil fuel reserves coupled with the environmental challenges pose by fossil fuel utilization make it necessary to search for better alternative fuels that have less adverse impact to the environment. Biodiesel and its blends as an alternative fuel in compression ignition (CI) engines are receiving more attention from researchers. This study investigates a blend of biodiesels from cottonseed oil and pure diesel prepared in percentage by volume in a proportion of 0:100, 10:90, 20:80 and 30:70 respectively. They were labeled as B0, B10, B20, and B30, and run on a single-cylinder, four stroke and water-cooled 165F diesel engine. The results show higher brake power for all blends when compared with pure diesel, with the lowest difference of 0.43% for B10 at a torque of 10 Nm and highest of 2.06% for B30 at 2 Nm torque. Specific fuel consumption (SFC) was also higher for the blends as compared to pure diesel, but the SFC is compensated with higher brake power. Pure diesel is observed to be thermally more efficient than biodiesel blends at low torque. The thermal efficiency difference ranges between 6.6–13.3% at 2 Nm. But at the torque of 10 Nm, the thermal efficiency of all blends is higher than pure diesel with about 3.3%. B30 shows better engine performance than pure diesel and the other two blends, but with slightly higher fuel consumption.

1.0 Introduction

Energy is one of the most significant contributing factors to the development of a nation. It is essential to the realization of basic needs for individuals and communities as well. The rise in the price of petroleum products, increase in its daily demand, uncertainty in its supply, and its negative environmental effect made it necessary for the world to find alternatives to fossil fuels such as diesel. This could be achieved either by improving the quality of the current fuels or by devising new alternative fuels for the future to replace the current ones through the utilization of renewable energy sources.

Vegetable oil is considered a suitable alternative to diesel fuel. Ramadhas, Jayaraj and Muraleedharan, (2004) and Tomasevic and Siler-Marinkovic, (2003) reported that vegetable oils such as cottonseed oil have a long hydrocarbon chain structure that contains 16-20 carbons with oxygen at one end. They are free from sulphur, metals and other impurities; this makes them possess good ignition features. But the disadvantages associated with some of these oils are low energy content, high viscosity, high density and more carbon deposit compared to pure diesel (Canakci and Van Gerpen, 2001). That is the reason most of the vegetable oils have low thermal efficiency. These disadvantages can be rectified to a certain extent using the processes of transesterification (Jadhav et al., 2016).

In transesterification process, vegetable oils and fats react with alcohol in the presence of catalyst to produce biodiesel. Glycerine is obtained at the end of this process as by-product; which can be used for a variety of industrial applications (Kumar, Maheswar, and Reddy, 2009). The biodiesel produced is biodegradable and non-toxic; it can be employed alone or mixed with diesel fuel in the compression ignition engine without necessarily modifying the engine parameters (Canakci and Van Gerpen, 2001).

Biodiesel from cottonseed oil is an environmentally friendly fuel derived from renewable energy sources. Apart from its environmental benefit, utilizing cottonseed oil biodiesel has additional economic benefits to countries where petroleum products are imported such as Nigeria. Cottonseed oil biodiesel utilization in Nigeria can bring about many benefits such as supporting the agricultural sector and rural economy, decrease in the reliance on imported crude oil for transportation and power generation, and reduction in greenhouse gases emission.

Different researchers have carried out different works on cottonseed biodiesel (Canakci and Van Gerpen, 2001; Fan et al., 2008; Jadhav et al., 2016; Kumar et al., 2009). Engine tests were carried out with either the pure biodiesel, with additives or with biodiesel blends. But in most cases, the focus is more on emissions reduction. As described by McCarthy, Rasul, and Moazzem (2011), reduction in the environmental impact of fuel diesel emissions is the main aim of using biodiesel. But engine performance is equally important as far as biodiesel utilization is concerned. Using biodiesel as an alternative is only possible provided engine performances are maintained because of its utilization or its blends.

Evaluation of engine performance, emissions and effects of additives on 4 different cottonseed biodiesel in comparison to pure diesel was conducted by Fan et al., (2008). The analysis in the research was carried out with only cottonseed biodiesel not its blend, and it focuses more on emissions reduction rather than engine performance. Kumar et al. (2009) also investigated the effect of varying the content of alcohol and catalyst on the viscosity of cottonseed biodiesel.

Properties of biodiesel highly depend on its source (Wu et al., 2009), and these properties determine the engine performance parameters and the nature of emissions. The performance parameters of a diesel engine are brake effective power (BEP), specific fuel consumption (SFC), and brake thermal efficiency (BTE). Diesel, biodiesel and biodiesel blends are used in CI engines to experimentally investigate these parameters at different engine torque.

The ratio of brake power produced to the mass of fuel consumed by an engine is what is termed as specific fuel consumption (SFC). Performance evaluation of an engine fueled with biodiesel and its blend compared to the same engine fueled with diesel shows the same thermal efficiency with higher SFC for biodiesel and its blend (Monyem, Van Gerpen, and Canakci, 2001). SFC is inversely proportional to thermal efficiency (Lapuerta et al., 2008). Since biodiesel is denser than pure diesel, is to some extent expected to have higher SFC (Munack, 2006). This increase in SFC is attributed to oxygen enhancement from fuel, and not from intake air (Rakopoulos et al., 2004). Increase in SFC was also reported by different researchers when using biodiesel or biodiesel blends compared to petroleum diesel (Alam, et al., 2004; Senatore et.al., 2000; Turrio-Baldassarri et al., 2004)

Lapuerta et al. (2008) described thermal efficiency as the ratio of power output to energy introduced through injected fuel. Canakci (2007) and Lapuerta et al. (2008) observed no significant changes in thermal efficiency when using biodiesel or its blends in CI engines.

Energy content per unit volume of biodiesel is lower than that of pure diesel (Dwivedi, Jain, and Sharma, 2011). Therefore, there is a likelihood of decrease in engine power output with more fuel consumption when using biodiesel compared to diesel. Though a slight increase in engine power output was observed by Usta (2005) for tobacco seed oil biodiesel blend in an indirect injection diesel engine.

In the present work, potentials of utilizing biodiesel from cottonseed oil blend with diesel as a substitute to pure diesel was investigated. Cottonseed biodiesel was produced using the transesterification process and blended in different percentage by volume with pure diesel. Performance parameters of a compression ignition engine fueled with pure diesel and diesel/biodiesel blends were experimentally investigated.

2. Materials and Method

2.1 Materials

The materials used in this research are:

- Biodiesel produced from cottonseed oil
- Pure petroleum diesel
- Stop watch
- Measuring cylinder
- Beakers
- Bottles
- Stirrer

2.2 Methods

2.2.1 Preparation of cottonseed oil biodiesel and its blends

The procedure for the transesterification of vegetable oil to produce biodiesel outlined in Jadhav et al. (2016) was adopted in this work. The process flow diagram of the procedure is shown in Figure 1.

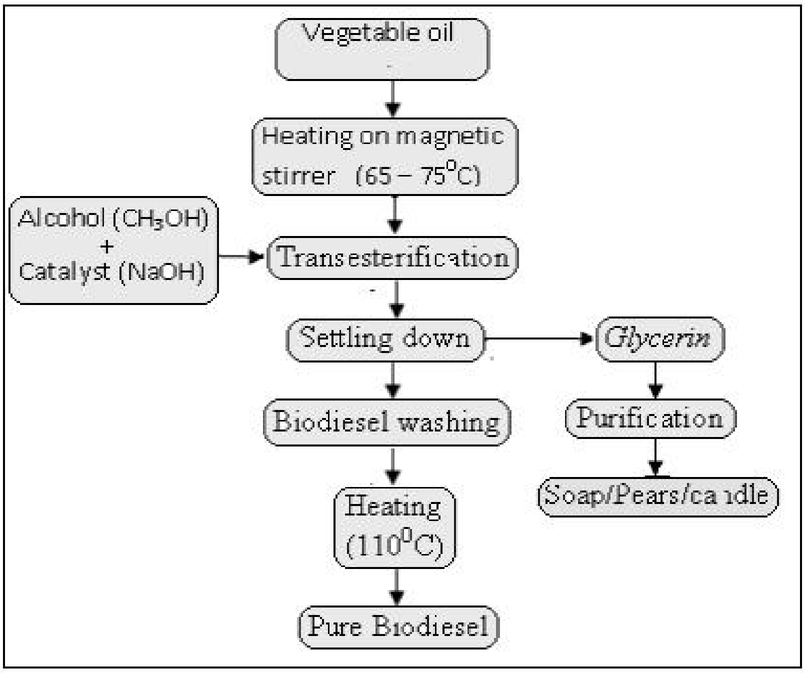

Figure 1: Biodiesel production process flowchart (Jadhav et al. 2016)

The production of the blends was conducted by measuring 100 mL of biodiesel from cotton seeds oil in a beaker, 900 mL of petroleum diesel was then added and the mixture was continuously stirred using a stirrer to form a ten percent (10% by volume) blend known as B10. The mixture (biodiesel blend) was poured into a clean bottle and closed, ready for engine test. Similar blends were further made with 200 mL of the biodiesel and 800 mL of petro-diesel, 300 mL of the biodiesel and 700 mL of the petro-diesel to form B20 and B30, respectively (see Figure. 2)

Figure 2: Diesel (B0) and various biodiesel blends

2.2.2 Biodiesel blends quality test

(a) Flash point (F.P)

An improved method was used for this determination. A 100 ml conical flask was filled to a specific level (10 ml) with biodiesel blend and was slowly heated at constant rate on the hot plate. The flash point was taken at the lowest temperature when an application of test flame caused the vapor above the sample to ignite.

(b) Density

The mass of a small empty bottle was determined using an electronic weighing balance. The bottle was then filled to the brim with the bio-diesel blends and the weight of the bottle and the bio-diesel determined. This procedure was repeated with B10, B20 and B30. The density was calculated using Equation 1;

$$\text{Density } (\rho) = \frac{w2 - w1}{v} \qquad (1)$$

where:

w2 = Mass of bottle + Sample

w1 = Mass of empty bottle

v = Volume of Sample

(c) Calorific value (CV)

An improved method was used for this determination. The wick was positioned in the locally made lamp. The weight of the empty lamp with 10 ml of the biodiesel blend was taken. The wick was lit and the biodiesel blend was used to heat the beaker containing 10 ml of water for 10 minutes after which the temperature of the water was recorded. The same procedure was repeated for blends of B10, B20 and B30. The calorific value/energy content was determined using Equation 2;

$$Q = mC\theta \qquad (2)$$

where:

m = Mass (kg)

C = Specific heat capacity (kJ/kgK)

θ = Temperature rise (oK)

(d) Kinematic viscosity

The viscometer was placed in the 1000 ml measuring cylinder filled with water and regulated to the appropriate temperature. The tube was filled up to a graduation mark over the left storage bulb with the bio-diesel blend. The bio-diesel was then sucked up to fill the higher storage bulb in the right of the tube and then released. The time taken for the bio-diesel to flow from the upper mark to the lower was observed and calculated. The kinematic viscosity of the bio-diesel blend was calculated using Equations 3 and 4;

$$\text{Kinematic viscosity (Y)} = \frac{\text{Absolute viscosity}(\eta_2)}{\text{Density}(\rho)} \quad (3)$$

$$\text{Absolute Viscosity } (\eta_2) = \frac{\eta_1 \rho_2 t_2}{\rho_1 t_1} \quad (4)$$

where:

η_1 = Absolute viscosity of water (8.90×10^{-4} Pa.s)

t_1 = Time of flow of water (s)

ρ_1 = Density of water (1000kg/m^3)

η_2 = Absolute viscosity of bio-diesel blend (Pa.s)

t_2 = Time of flow of bio-diesel blend (s)

ρ_2 = Density of bio-diesel blend (kg/m^3)

The same procedure was repeated using B10, B20, B30 and water was taken as the reference

2.2.3 Engine test

The engine test was carried out using a 2 stroke single cylinder diesel engine at the Department of Mechanical Engineering, Bayero University Kano. The specifications of the said engine are given in Table 1. The engine test was performed, and the parameters measured include engine torque, engine speed, exhaust temperatures and height of air in the manometer. This study was conducted to investigate the engine performance run on different biodiesel from cottonseeds/petro-diesel blends (B10, B20, and B30).

Table 1: Test Engine Specifications

Parameter	Specification
Engine model	Vikin Super 165F diesel engine
Type of Engine	2-stroke single cylinder stationary diesel engine
Weight	40 kg
Bore	65 mm
Stroke	70 mm
Rated power	2.43 kW
Rated speed	2600 rpm
Cooling	Air-cooled

3. Results and Discussions

The results obtained from the experiments conducted for engine performance are evaluated. Before carrying out this experiment, the properties of the biodiesel blends were determined and compared to that of petroleum.

3.1 Properties of Biodiesel and Biodiesel Blends in Comparison with Diesel

The properties of biodiesel blends at different percentage by volume in comparison to that of petroleum diesel are shown in Table 2

Table 2: Properties of Biodiesel in Comparison with Diesel and Blends

Properties	B0	B10	B20	B30	Protocol	Min-Max
Density (kg/m^3)	824	832	839	847	ASTM D1448	800 - 900
Kinematic viscosity (cst)	1.9	2.4	3.7	3.9	ASTM D2217	1.9 – 4.1
Flash point (°C)	58	72	78	82	ASTM D93	130 min
Calorific Value (MJ/kg)	43.20	42.41	42.28	42.10	ASTM D6751	34 - 45

The density of the biodiesel blends is found to be within the range of the ASTM standard. It is observed that Biodiesel blends have higher viscosity and flash point than petroleum diesel. The viscosity of all the blends is also within the limit of the ASTM standard. The increase of density and viscosity with increase in the percentage of biodiesel in the blend is because the biodiesel is denser and more viscous than pure diesel. For the flash point, all the blends including the diesel have values lower than the minimum of 130°C. Finally, the calorific value also falls within the standard which ranges from 34-45 MJ/kg. The calorific value decreases with increase in the percentage of biodiesel in the blend as a result of lower amount of energy contained in biodiesel compared to pure diesel.

3.2 Performance Evaluation

Significant performance parameters of a diesel engine such as Brake Thermal efficiency (BTE) and Specific fuel consumption (SFC) are evaluated for cotton seed oil biodiesel blend and diesel. SFC can be used to compare engine performance of fuels with distinct energy content.

3.2.1 Analysis on the SFC

Figure 3 shows the SFC variation of petroleum diesel and its blends of cottonseed oil at different torque. The SFC of the blends is higher at all torques compared to the petroleum diesel. This is attributed to the lower energy content of the blend compared to pure diesel. At lower torque the SFC is higher for the blends and pure diesel, and as the torque increases the SFC decreases. Not much significant difference is observed among the SFC of blends at all torques. It is also observed that as the torque increases, the difference in SFC of the pure diesel and the blend decreases. The lowest SFC occurs at the torque of 10 Nm; which is due to the lower heating value, higher viscosity and density of biodiesel (cottonseed oil).

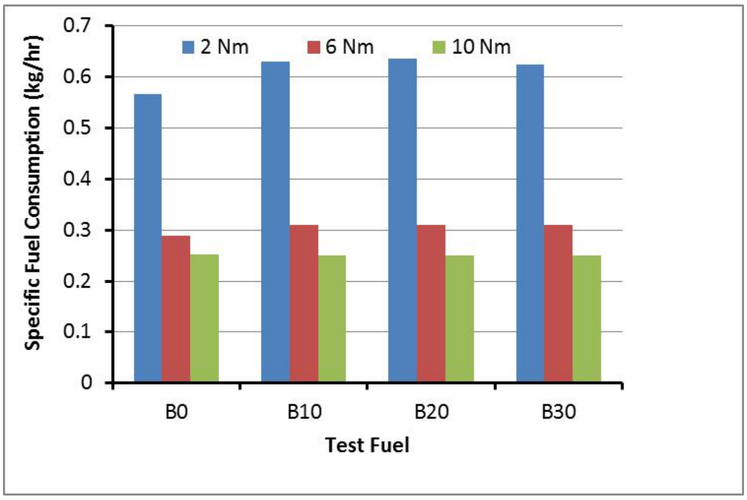

Figure 3: Specific fuel consumption of diesel and blends

3.2.2 Analysis on the brake power

Figure 4 shows the Brake power of diesel fuel (B0) and various biodiesel blends (B10, B20 and B30) at torque of 2Nm, 6 Nm and 10 Nm, respectively. It is noticed that at 2 Nm torque, the brake power of the blends were slightly higher than the diesel fuel except for B20 which is the same as B0. Also, at 6 Nm torque the brake power for the blends are higher compared to the petroleum diesel by 0.8%. Finally, at 10 Nm torque, the brake power of the blends are higher compared to the diesel fuel, the brake power of B20 at this torque is higher compared to the other blends; which has a value of 2450 W. This variation could be as a result of the higher fuel flow rate. It was found that an increase in torque resulted in increases in the brake power of the engine.

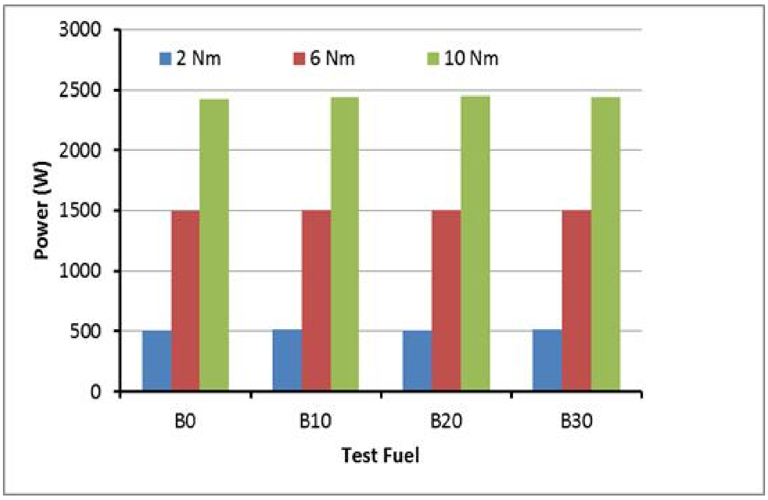

Figure 4: Brake Power of diesel and blends at different torques

3.2.3 Analysis on the brake thermal efficiency

BTE increases with increase in the engine load as shown in Figure 5. As the percentage blend increases there is a slight variation in the BTE with respect to increase in the torque. Pure diesel (B0) has the highest BTE at 2 Nm compared to all the blends, likewise at 6 Nm. But at 10 Nm B10, B20 and B30 have the highest compared to B0. This implies that at high torque the blend is thermally more efficient than pure diesel and vice versa. This could be as a result of the increase in the rate at which the biodiesel burn in the blends.

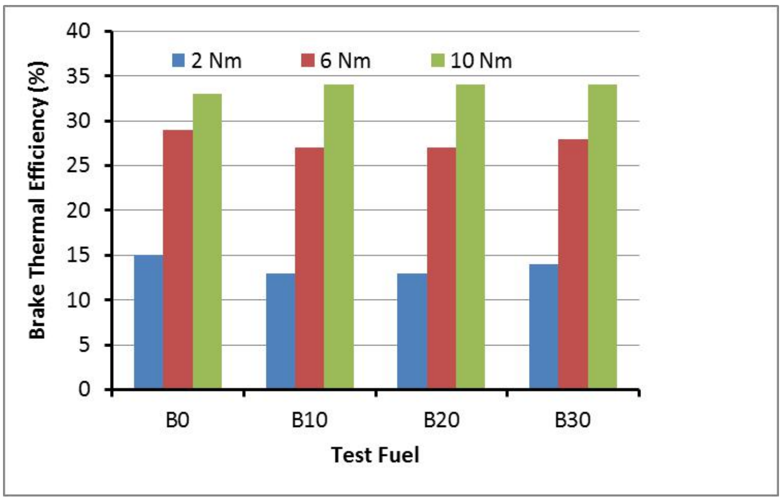

Figure 5: Brake Thermal Efficiency (BTE) of diesel and blends

3.2.4 Analysis on the exhaust gas temperature

The variation of exhaust gas temperature with torque for diesel and its blends with cotton seed oil are shown in Figure 6. B0 has the highest exhaust temperature of 175°C at 2 Nm torque.

The lowest at the same torque are B20 and B30 which are at an exhaust temperature of 171°C. B10 has the same exhaust temperature as B0 at 2 Nm. Similarly, at 6 Nm the exhaust temperature remains constant for B10, B20 and B30 with a value of 233°C except for B0 which has an exhaust temperature of 235°C. Furthermore, at 10 Nm, it is observed that there is an increase in exhaust temperature with decrease in the percentage blends. Decreasing the percentage of biodiesel in the blend means decreasing its cetane number; this brings about longer ignition delay time which results in higher exhaust gas temperature.

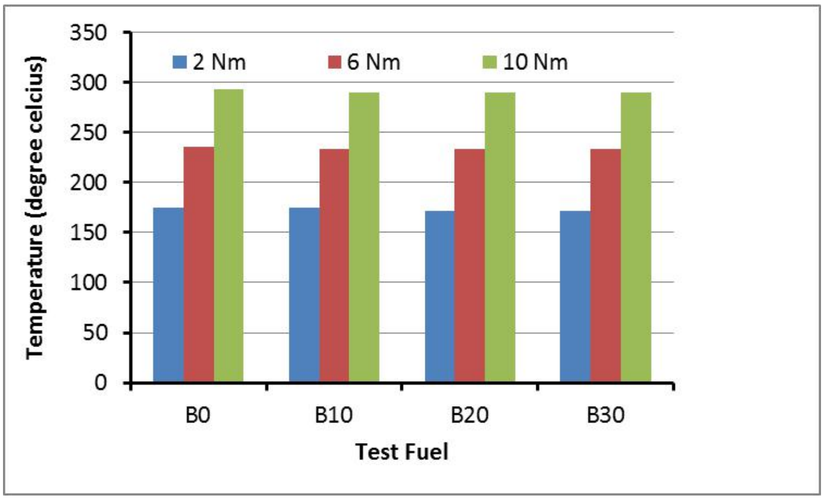

Figure 6: Exhaust temperature of diesel and blend

3.2.5 Analysis on the Brake power Vs Fuel consumption of the blends

It was observed in Figure 7 that the worst blend at 2 Nm is B20; it consumes more fuel and at the same time produces less power. For the other two blends, though they consume more fuel than pure diesel but they produce more brake power; which means the high fuel consumption is compensated with more power produced. The same pattern is observed in Figure 8 at a torque of 10 Nm.

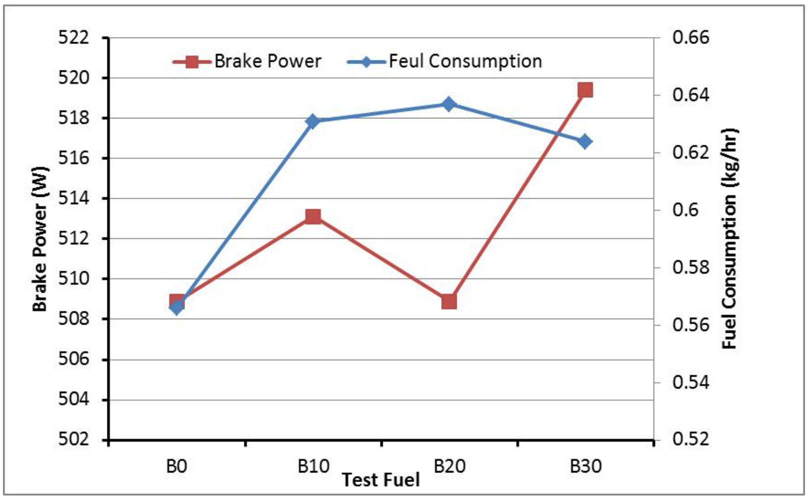

Figure 7: Brake Power Vs Fuel Consumption at 2 Nm

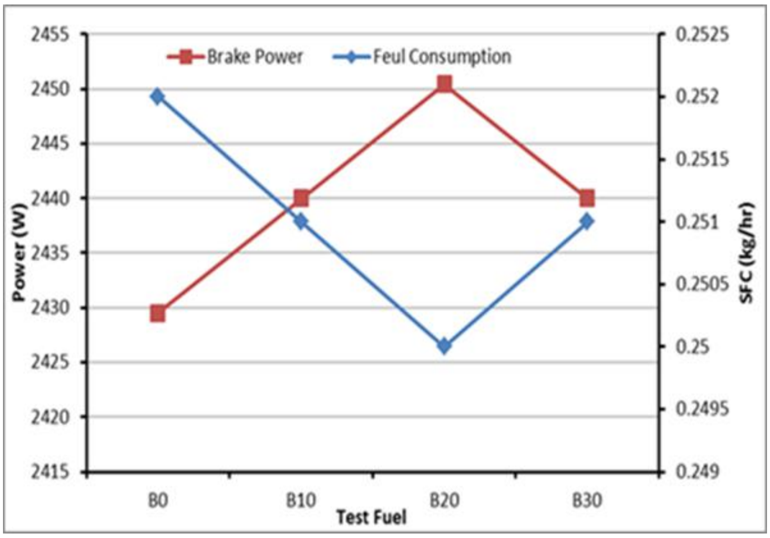

Figure 8: Brake Power vs Fuel Consumption at 10 Nm

4. Conclusion

Vegetable oil from cotton seed is converted into biodiesel using transestrification process. This biodiesel is mixed with pure diesel in altered percentage to produce three different blends. The tests for the properties of biodiesel demonstrate that almost all the properties of biodiesel are in close agreement with diesel fuel. Test was carried out using these blends as alternative fuel in a diesel engine to investigate its performance. The results obtained were evaluated and compared with the results obtained from the same engine but run on pure diesel. Higher specific fuel consumption was observed for the blends at all torques compared to pure diesel. Almost all the blends have higher break power than diesel at all torques. It is equally observed that at high torque the blends are thermally more efficient than pure diesel and vice versa. Exhaust temperature for diesel is higher than that of the blend at all torques.

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