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ENGINE PERFORMANCE OF BLENDS OF PALM KERNEL OIL BIODIESEL UNDER VARYING SPEED AT CONSTANT TORQUE

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ABSTRACT
This study conducts a comparative evaluation the effect of using palm kernel oil (PKO), pure petroleum diesel and their blends (B5, B10, B20, B30, B40, and B100), on the performance of a four-cylinder CI diesel engine (David Brown 990: 58hp; 2WD), at Farm Power and Machinery Test laboratory Centre (FPMTLC), Department of Agricultural and Bioresources Engineering, University of Nigeria, Nsukka. The objective of the study was to determine the fuel consumption rates, energy expended, brake specific fuel consumption, and brake thermal efficiency, under varying operating speeds (700 – 1900rpm) at constant torque. Each fuel test was conducted using the Heenan-Froude hydraulic dynamometer engine-test-bed; pure petroleum diesel (B0) was used to generate the baseline data. Variables calculated were analyzed, then compared with each other to determine the differences in the engine performance and also to determine the optimum test fuel. The results obtained show that B10 had the overall optimum energy output, fuel consumption rates, and brake specific fuel consumption of 5431.809J, 3.42E-07 m^3/s, and 0.16569l/KWh, respectively at the highest engine speed of 1900. B10 had an excellent brake thermal efficiency of 60.6% but was not better than B100, which showed a higher value of 66.95%. From the analysis, B10 is the optimum test fuel and can be used as an alternative fuel in David Brown 990 (58hp; 2WD) or similar CI diesel engines without any engine modification, even though B100 showed potential as an alternative to fossil diesel. Biofuel production grows through integrated aquaculture and algae production; the algae oil will serve as a raw material for biofuel production

Keywords: *Blends, Biodiesel, Brake Specific Consumption, Diesel Engine, Fuel Consumption rate, Thermal Efficiency.*

1. INTRODUCTION

Due to increased awareness of the implication of climate change, there is an urgent need to harness biofuels in transportation and agricultural operations. Emissions from transportation and agricultural operations contribute significantly to a high level of carbon emissions from Nigeria [1]. In order to reduce the growing emission trend from Nigeria, there is a need to introduce biodiesel, renewable fuel, in agricultural operations.

Biodiesel is a renewable biofuel derived from animal pat and vegetable oil. The production of biodiesel is through the process of transesterification, which involves the use of alcohol, a catalyst acid or base catalyst), and vegetable oil. Biodiesel is an alternative fuel for diesel engines; it mixes with fossil diesel resulting in biodiesel blends. Biodiesel is renewable and is environmentally friendly [2, 3]. Fuel properties of biodiesel are similar to the properties of fossil diesel, as shown by many researchers around the world. Other researchers point to the fact that the combustion of biodiesel highly reduces carbon dioxide (CO_2) emission to the atmosphere. Some other findings show that biodiesel has a high cetane index, which is a required viable property for fuels used in diesel engines [4]. Biodiesel increase engine

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lubricity and reduces exhaust gas temperature, thus reducing overall operating temperature [5]

In Nigeria, the use of biodiesel has not gained full attention; there is a need for increased significant field tests, even though laboratory-scale production and testing are dominant. In countries such as Brazil and Germany, an alternative to 100% biodiesel concentration is used, named biodiesel blends [6, 7]. Biodiesel blends significantly reduce CO_2, NO_x emissions, as shown by some researchers. Such blends as ethanol/premium motor spirit are currently used as an option to reduce the total cost of using 100% ethanol [8, 9]. Biodiesel blends are used in Diesel enquires if the properties are related to a great extent to that of fossil diesel. Such properties will be suitable in order to avoid engine modification. Palm kernel oil is highly available in Nigeria. Even though it is an edible oil, with increased agricultural production, it can serve as viable raw material for biodiesel production. Standards for biodiesel fuel were documented by the European Union and the American Society of Testing and Materials (ASTM). The essential aspects of these standards are the cetane index, viscosity, iodine index, and caloric value [10, 11].

Biodiesel can be used in agriculture to power diesel engines in an unmodified state; this increases the potential of replacing fossil fuels. The engines supply power for field operations, post-harvest operations, and other operations. In this study, the performance of various blends of biodiesel derived from palm kernel oil in a diesel engine was studied in order to determine the viable fuel. The variable considered were fuel consumption rates, brake thermal efficiency (BTE), brake specific fuel consumption (PSF), and energy developed by the fuel. All tests were conducted at varying speed constant torque scenario.

2. MATERIAL AND METHODS

2.1 Experimental Test Bed.

This study utilized a tractor wish engine specification shown in Table 1. The tractor was linked to a dynamometer with the specification shown in Table 2. The dynamometer was connected to a 10 liters water tank. Other test apparatus included a fuel measuring burette with a by-pass pipe. A 100cm3 measuring cylinder was used to measure the exact quaintly of fuel needed. The dynamometer was used to control the torque at a constant value as the engine was increased. The test engine fuel line was modified to adapt to the calibrated cylinder.

Table 1: Specifications of the test Engine

Engine	Specifications
Name	Tractor
Model	1992 Model
Make	David Brown
Country of Make	United Kingdom
Rated Power	58hp
Wheel Drive	2WD (2 Wheel Drive)
Type	CI (Compression Ignition)
Number of Cylinders	4 Cylinders
Rated Speed	2600rpm (Hour at 1412rpm)
Fuel type	AGO (Diesel Fuel)
Strokes	Four strokes engine

Table 2 Specifications of the Hydraulic Dynamometer

Dynamometer	Specifications
Size	DPX2
Order Number	BX 34576
Maximum Power (KW)	112KW at Revolution minutes of 4040/7500
Make	Heenan-Froude: Worcester, England
Model	DPX
Serial Number	TE 87/3940
Type	Hydraulic Dynamometer

2.2 Test fuel

The biodiesel was produced at the fuel production plant located at the biodiesel production facility at the Department of Agricultural and Bioresources Engineering, University of Nigeria Nsukka. Palm kernel oil was used as raw material to produce biodiesel through the process of base-catalyzed transesterification. Methanol and sodium Hydroxide were used as reactants in the production. The biodiesel production occurred at 60ºC at a pressure of 2 atmospheres; it adequately was purified and allowed to stand for 18 hrs. ASTM standard fuel test procedure was used in determining the fuel properties. The primary fuel properties of the B100 is shown table 3. 50 litres of pure petroleum diesel (BO) was total fuel station in Nsukka, Enugu State Nigeria. 25 liter of B100 was produced and used in the experiment. The palm kernel oil biodiesel was blended on a volume basis with pure petroleum diesel to obtain the blends used as (BX), where " B" represents pure petroleum diesel and represent the percentage of PKO Biodiesel. Even samples were prepared, which includes BO, B5, B30, B40, and B100.

Table 3: Some Fuel Properties of the methyl ester PKO biodiesel and Premium Diesel

Properties	PKO Biodiesel	Premium Diesel (PD)
Density @ 15°C (kg/m^3)	876.75 (ASTM-D4052)	873.9
Cetane Index	62.4 (ASTM-D613)	50
Kinematic Viscosity (m/s^2 @ 40°C	3.250 (ASTM-D445)	3.276
Flash Point (°C)	131.2 (ASTM-D93)	68
Heating Value (MJ/kg)	37.9 (ASTM-D4809)	45.86
Oxygen Content (wt%)	13.57	-
Cloud point (°C)	21 ASTM-D2500)	8

2.3 Experimental Procedure

The tractor was coupled to the dynamometer using a PTO propeller inserted in the PTO shape. The engine was started and allowed to idle until the average operating temperature attained. The rack was then adjusted to an optimum position, and the fuel tests carried out using a measuring burette with by-pass pipes attached to the engine. The engine speeds used for the fuel tests were 700rpm, 1300rpm, and 1900 rpm, with the required engine torque, kept constant at 225nm during the test. Experiments were carried out initially using pure petroleum diesel fuel (B0) to generate the baseline data. After recording the data for the reference fuel, other tests were carried out for B5, B10, B20, B30, B40, and B100 and recorded. Record items include all data necessary to calculate the required results as well as all data necessary to reproduce the test. However, before running the engine with new test fuel, it was necessary to change the fuel filters and bleed the system. This was done to ensure a complete transition from one test fuel to another and to escape all traces of air from the system. After each test interval, various parameters such as time, volume, torque, and speed were measured and recorded at the various engine speeds at constant torque. Engine performance tests were replicated three times and the means of each measured parameter used to determine the engine performance of the test fuels based on the following variables; fuel consumption rates, engine power, brake specific fuel consumption, and brake thermal efficiency.

Nonetheless, to measure the fuel consumed in each test, a two-way valve fitted with a burette was attached to the engine, and the fuel consumption rate determined by recording the time "t" taken for 250ml of fuel to flow under gravity into the engine. The variables calculated were analyzed using tables, plots (graphs), and statistical tools and compared with each other in order to determine the differences in the engine performance and also to determine the optimum test fuel. Each test was repeated twice for accuracy.

3. RESULTS AND DISCUSSIONS

The effects of varying speed at constant torque on some selected engine performance parameters were investigated. The constant torque scenario simulates tractor operation during the transportation of agricultural products from farm to store.

3.1 Energy Expended

As shown in Figure 1, B10 had the highest energy output of 5431.809J at an engine speed of 1900 rpm. B100 follows this with a value of 5267.6J. The trend shows that B10 and B100 biodiesel blends are suitable for constant load, high speed demanding situations. For other scenarios of constant torque varying speed, B10 exhibited high engine energy output with values of 4853.76J and 5213.86J for 700 and 13000rpm.

3.2 Fuel Consumption Rates

From Figure 2, the fuel consumption rates reduce from B0 to B100 at an engine speed of 1300 and 1900. Specifically looking at Figure 2, B10 had the lowest consumption rate of 3.42E-7, 3.03E-7, and 2.07E-7 for 1900, 1300, and 700rpm, respectively. The fuel blend with the next lowest consumption rate is the B100, except for engine speed of 1300, where B30 had the second-lowest fuel consumption rate. Overall, B10 and B100 had the lowest fuel consumption rates.

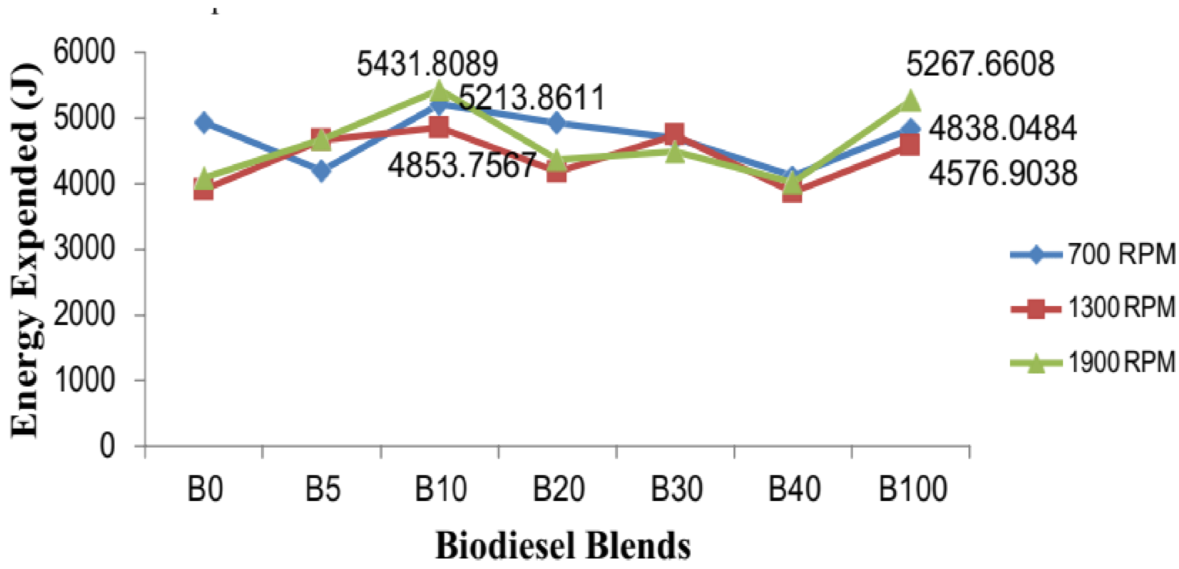

Figure 1: Energy Expended by the different fuel blends

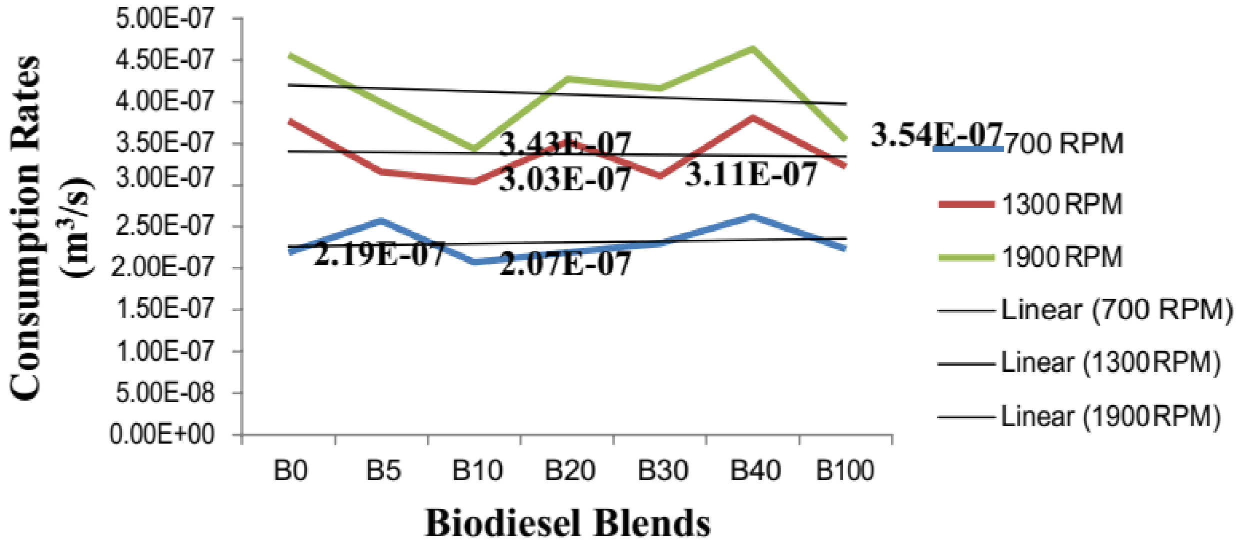

Figure 2: Fuel Consumption Rates of the different fuel blends

3.3 Brake Thermal Efficiency

Brake thermal efficiency is a measure of how effective the chemical energy of the fuel is converted to mechanical power or work, according to [12]. Figure 3 shows the variation of brake thermal efficiency of various blends at constant torque with varying speeds. B10 and B100 had the highest values of 60.6%, 58.17%, 54.15%, and 66.95%, 61.49%, 58.17% respectively for rotatory speeds of 700, 1300, and 1900 rpm.

3.4 Brake Specific Fuel Consumption (BSFC)

BSFC is a performance criterion that shows the amount of fuel used by the engine to develop one-kilowatt shaft power. BSFC has a strong correlation with the heating value of fuel, which implies that the higher the heating value of a fuel, the higher its brake specific fuel consumption. From Figure 4 observed that B10 had the highest fuel economy at all engine speeds with BSFC of 0.1726, 0.1854, and 0.1657 l/KWh; B100 had the second-highest fuel economy with BSFC values of 0.186, 0.1966, and 0.1709 l/KWh for engine speeds of 700, 1300, and 1900 rpm respectively.

3.5 Policy Implications of the study

From the overall results, B10 and B100 exhibited the most acceptable engine performance properties. The B100 had a higher cetane index than that of premium diesel, thus showing the most recommendable result for thermal brake efficiency (BTE).

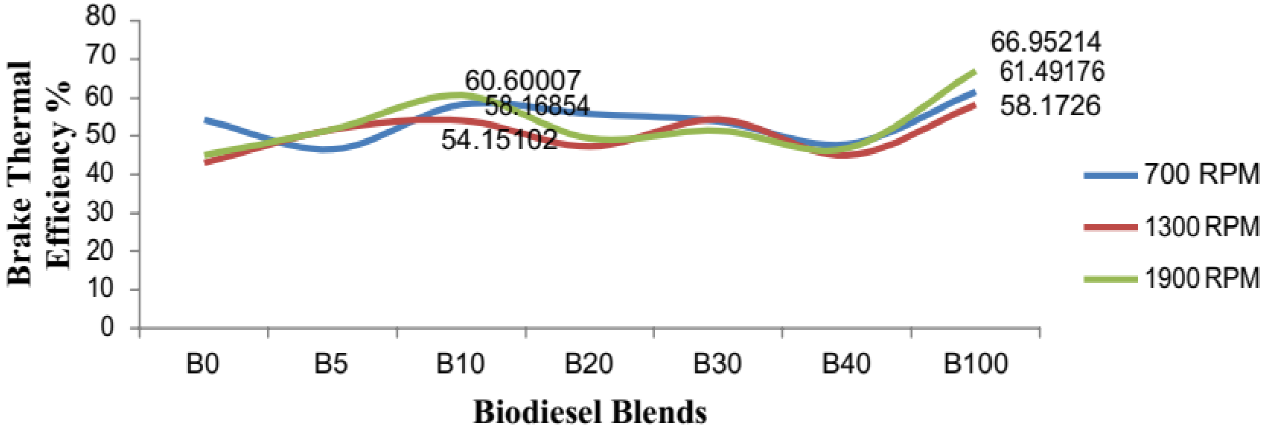

Figure 3: Brake thermal efficiencies of different fuel blends at varying speeds

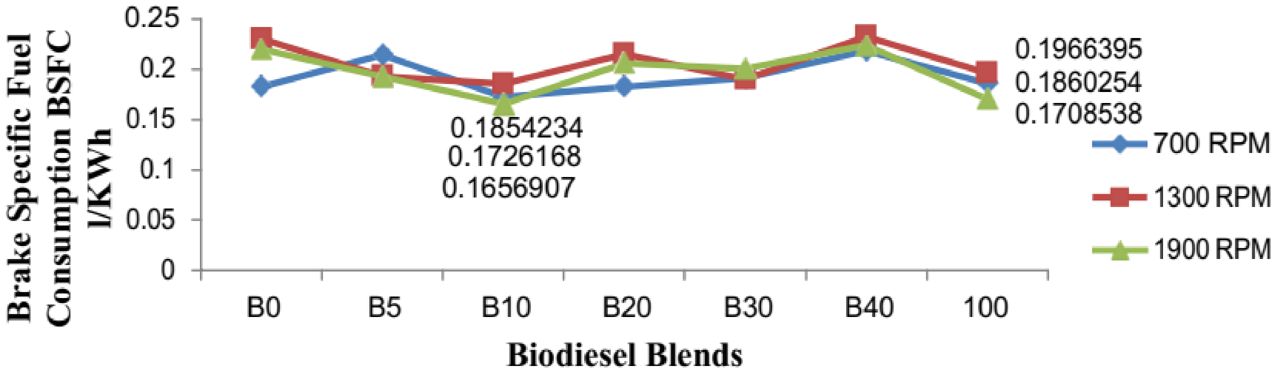

Figure 4: Brake specific fuel consumption of the different fuel blends

The implication is that the use of biodiesel as an alternative fuel for premium diesel should be encouraged in Nigeria. As other researchers like [13 - 15], showed that the exhaust gas emissions from B100 were far acceptable to emissions from B0 and other blends. It is also encouraging to note that developing countries can develop transition policies to B100 by the stepwise introduction of biodiesel blends, with the goal of a full transition to renewable fuels.

4. CONCLUSION

Biodiesel made from palm kernel oil was mixed with premium diesel and ran on non-modified diesel engine at varying speeds of 700, 1300, and 1900 rpm at constant torque of 225Nm. It was observed that fuel-specific properties affected the behavior of each fuel blend. From the results, B10 had the overall most acceptable energy production, consumption rates, brake thermal efficiency, and brake specific fuel consumption of 5431.81J, 3.43E-7 m3/s, 60.6%, and 0.1657l/KWh respectively for engine speed 1900 rpm. B100 showed the second most acceptable results for energy production, consumption rates, brake thermal efficiency, and brake specific fuel consumption of 5267.66J, 3.54E-7m3/s, 66.95%, and 0.1708 l/KWh respectively at an engine speed of 1900 rpm. It can be deduced that the diesel fuel blend does not cause any adverse effect on the engine or reduce engine performance but increase the desired performance index and reduces harmful effects to the atmosphere. Finally, B100 performed better than B0 due to having higher brake thermal efficiency (BTE).

More engine testing at higher rotating speeds, biodiesel blends, and emission tests are necessary to validate the possibility of using biodiesel blends as alternatives for fossil diesel. Fuel tests on biodiesel blends produced from Jatropha, benniseed, and algae oil are necessary to determine its feasibility for use in agricultural operations.

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