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ENGINE PERFORMANCE ANALYSIS OF PALM KERNEL OIL-BASED BIODIESEL BLENDS ON SPEED VARIATIONS OF A 4-CYLINDER ENGINE AT CONSTANT TORQUE

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Abstract

Biodiesel made from the transesterification of plant-derived oils is an important *alternative fuel source for diesel engines. Several disparate studies have emphasized the significance of biodiesels in emission reduction and engine efficiency. The present study examined the effect of using palm kernel oil (PKO), pure petroleum diesel, and its blends on the fuel consumption rates, energy expended, brake-specific fuel consumption, and brake thermal efficiency of a four-cylinder tractor under varying operating speeds (700 – 1900rpm) at constant torque. The study was conducted at a large farming site in Anambra State, Nigeria. The findings indicated that PKO biodiesel blends had the overall optimum energy output, fuel consumption rates, and brake-specific fuel consumption, respectively, at the highest engine speed of 1900. Although B10's rating of 60.6% for thermal brake efficiency was impressive, it was lower than B100's 66.95 %. Based on the results, B10 is the best gasoline for testing and may be used as a replacement fuel in four-cylinder farm tractor engines with no modifications. The study concludes that biodiesel blends showed potential as an alternative to fossil diesel.*

Keywords: *biodiesel, PKO, petroleum diesel, diesel engine*

INTRODUCTION

The overwhelming concerns due to the over-exploitation of fossil resources necessitate using alternative energy resources (Pasha et al., 2021). Utilizing biofuels in agricultural and transportation processes is urgently needed due to growing awareness of the effects of climate change. Many of Nigeria's high carbon emissions come from the agriculture and transportation sectors. (Agarana et al., 2017; Akbar et al., 2021; Amin et al., 2020; Charabi et al., 2020; Koondhar et al., 2021; Pendrill et al., 2019; Riski et al., 2021; Yaacob et al., 2020) Biodiesel is an alternative to conventional petrodiesel for compression-ignition engines (Knothe & Razon, 2017). It describes a renewable fuel that must be used in agricultural operations to minimize the rising emission trend. Biodiesel describes potential alternative energy sources that are derivable from renewable and low-grade origin using various processes (Rizwanul Fattah et al., 2020). It has the potential to alleviate environmental pressures and achieve sustainable development (Mahlia et al., 2020). Biodiesel has been considered one of the most adaptable alternatives to fossil-derived diesel, with similar properties and numerous environmental benefits (Pasha et al., 2021). Authors have described transesterification as an essential pathway to create biodiesel (Leung et al., 2010)., which uses alcohol, acid or base catalyst, and vegetable oil to produce biodiesel. Biodiesel is recognized as a potential alternative renewable energy fuel that can be readily available in many parts of the world (Verma et al., 2021).

Numerous studies conducted worldwide have demonstrated that the fuel attributes of biodiesel are comparable to those of fossil diesel. Other scientists emphasize how much less carbon dioxide (CO2) is released into the atmosphere when biodiesel is burned. According to some other research, biodiesel has a high cetane index, a necessary characteristic for fuels used in diesel engines. Biodiesel increases engine lubricity and reduces exhaust gas temperature (Jayaprabakar et al., 2017), thus reducing overall operating temperature. Although biodiesel is widely produced and tested in laboratories, it has not yet received sufficient attention in Nigeria. More extensive field testing is required.

Previous studies (Kaya & Kökkülünk, 2020; Komariah et al., 2013; Roy et al., 2013; Shahir et al., 2015; Shamun et al., 2018)indicated that biodiesel blends significantly reduce CO^2 and NOx emissions. As a current alternative to employing 100% ethanol, mixtures like ethanol/premium motor spirit are employed to cut costs. Blends of biodiesel and fossil diesel are employed in Diesel engines if their qualities are highly similar. Such characteristics will help prevent the need to modify engines. In Nigeria, palm kernel oil is common and reachable. A rise in agricultural output makes this edible oil a potential raw ingredient for biodiesel manufacturing. Standards for biodiesel fuel were documented by the European Union and the American Society of Testing and Materials (ASTM). The cetane index, viscosity, iodine index, and caloric value of fuel are essential factors in determining the quality of ignition in compression ignition (CI) engines.

In its unaltered form, biodiesel can power diesel engines in farming, expanding the possibility of using it to replace fossil fuels. The engines provide energy for use in the field and after harvest. This study studied the performance of various blends of biodiesel derived from palm kernel oil in a diesel engine to determine the viable fuel. The variable considered was fuel consumption rates, thermal brake efficiency (BTE), brake-specific fuel consumption (PSF), and energy developed by the fuel. All tests were conducted at varying speeds at constant torque scenarios. The study's main objective is to determine the engine performance of palm kernel oil biodiesel blends under varying speeds at constant torque.

Materials and method

This study is an experimental study that utilized a tractor linked to a dynamometer with determined specifications. The dynamometer was connected to a 10 liters water tank. Other test apparatuses include a fuel-measuring burette with a by-pass pipe. A 100cm3 measuring cylinder for measuring the exact quaintly of fuel needed. The dynamometer was used to control the torque at a constant value as the engine increased. The test engine fuel line was modified to adapt to the calibrated cylinder. This study conducts a comparative evaluation of 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), in a large farming yard in Anambra State. The research was conducted to learn how thermal brake efficiency changed across a wide range of operating speeds (700- 1900rpm) while maintaining constant torque. The Heenan-Froude hydraulic dynamometer engine test bed (Nwakaire et al., 2020) was used to conduct the fuel comparisons, with pure petroleum diesel (B0) serving as the reference standard.

Experimental fuel

Palm kernel oil was used as raw material to produce biodiesel through 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 was purified and allowed to stand for 18 hrs. The quality of produced biodiesel was examined according to the standard procedures defined by the American Society for Testing and Materials (ASTM). Fifty liters of pure petroleum diesel (B0) was purchased from a filling station, while 25 liters of B100 was produced and used in the experiment. Biodiesel can be used in pure form (B100) or may be blended with petroleum diesel at any concentration if its specifications are identical to the international standard specifications provided by the American standard for testing materials (ASTM) or EN14214 in the European Union for alternative fuels. The palm kernel oil biodiesel was blended on a volume basis with pure petroleum diesel to obtain the blends, which include 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 @ 15oC (kg/m3)	876.75 (ASTM-D4052)	873.9
Cetane Index	62.4 (ASTM-D613)	50
Kinematic Viscosity (m/s2 @ 40oC	3.250 (ASTM-D445)	3.276
Flash Point (oC)	131.2 (ASTM-D93)	68
Heating Value (MJ/kg)	37.9 (ASTM-D4809)	45.86
Oxygen Content (wt%)	13.57 -	
Cloud point (oC)	21 ASTM-D2500)	8

Experimental Procedure

The dynamometer was connected to the tractor by a PTO propeller positioned within the PTO opening. After turning on the ignition, the engine was let to run at a crawl until it reached its typical operating temperature. After the rack was placed in the most advantageous position, the fuel tests were carried out with the assistance of a measuring burette with by-pass pipes attached to the engine. The engine speeds utilized to test the fuel were 700 rpm, 1300 rpm, and 1900 rpm, and the required engine torque was maintained at 225 nm throughout the test. Experiments were carried out initially using pure petroleum diesel fuel (PDF) so that baseline data could be generated. Following the recording of the data pertaining to the reference fuel, additional tests were carried out and recorded pertaining to B5, B10, B20, B30, B40, and B100. Items that are included in the record are all of the data that is necessary to reproduce the test, as well as all of the data that is necessary to calculate the needed results.

However, before starting the engine with the new test gasoline, it was necessary to bleed the system and replace the fuel filters. This was done to guarantee a smooth transition from one test fuel to another and eliminate any traces of air remaining in the system. Upon completion of each testing interval, several metrics, including time, volume, torque, and speed, were subjected to measurement and recording while the engine was operating at various speeds while maintaining a consistent torque. The engine performance tests were repeated three times, and the averages of each measured parameter were used to determine the engine performance of each test fuel in relation to the following variables: fuel consumption rates, engine power, brake-specific fuel consumption, and brake thermal efficiency.

However, to determine how much fuel was used during each test, a two-way valve equipped with a burette was attached to the engine. The fuel consumption rate was then determined by recording the amount of time it took for 250 milliliters of fuel to flow into the engine when it was subjected to the force of gravity. The calculated variables were analyzed with tables, plots (graphs), and statistical tools, then compared with one another to determine the differences in the engine performance and the optimal test fuel. This was done to determine which fuel was best for the test. The accuracy of each test was ensured by performing it twice.

Results and Discussions

Some engine performance parameters were studied in relation to how they changed when the speed was changed while the torque remained the same. Tractor operation during the delivery of farm goods to a retail outlet can be modeled using the constant torque scenario.

Energy Expended

As can be seen in Figure 1, B10 achieved the highest energy output of 5431.809J when operating its engine at 1900 revolutions per minute. This is followed by B100, which has a value of 5267.6J. The current trend demonstrates that B10 and B100 biodiesel blends are suited for challenging scenarios that involve steady load and high speed. B10 displayed a high engine energy production, with values of 4853.76J and 5213.86J at 700 and 13000rpm, respectively, for different scenarios involving constant torque and changing speed.

Fuel Consumption Rates

Accordingly, Figure 2 indicates that the rates of fuel consumption drop from B0 to B100 when the engine speed is increased from 1300 to 1900. When specifically looking at Figure 2, B10 had the lowest consumption rate, with values of 3.42E-7, 3.03E-7, and 2.07E-7, respectively, for 1900, 1300, and 700rpm. The B100 fuel mix has the next-lowest consumption rate, with the exception of when the engine speed was 1300, in which case the B30 fuel blend had the second-lowest consumption rate. Generally, the fuel consumption rates for the B10 and the B100 were the lowest.

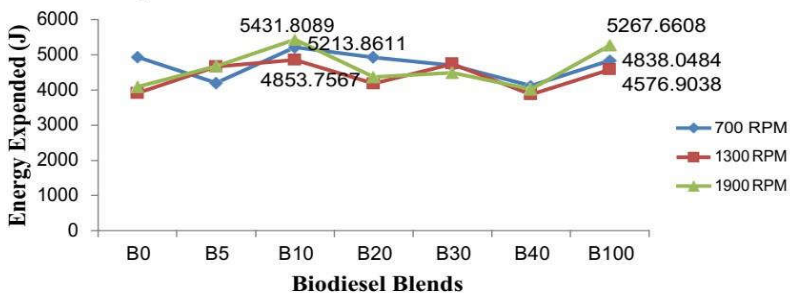

Figure 1: Energy Expended by the different fuel blends

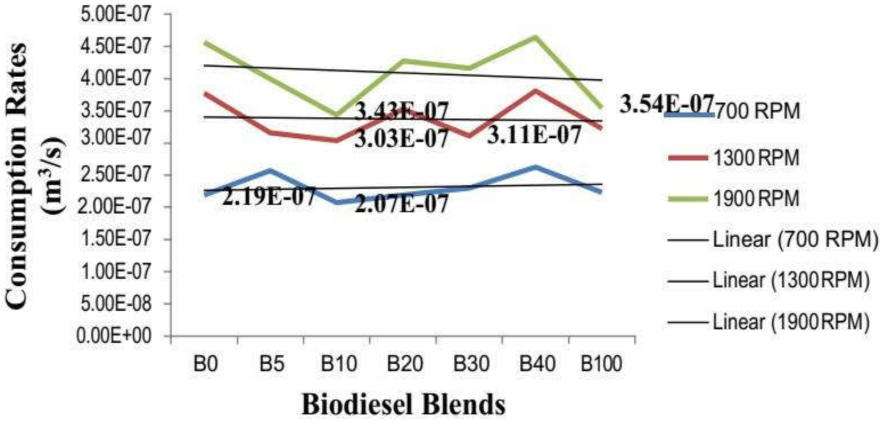

Figure 2: Fuel Consumption Rates of the different fuel blends

Brake Thermal Efficiency

Brake thermal efficiency measures how effectively the chemical energy of the fuel is converted to mechanical power or work. Figure 3 shows the variation of thermal brake 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%, and 58.17%, respectively, for rotatory speeds of 700, 1300, and 1900 rpm.

Brake Specific Fuel Consumption (BSFC) BSFC is a performance criterion that shows the fuel the engine uses 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. 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 BSFC values of 0.186, 0.1966, and 0.1709 l/KWh for engine speeds of 700, 1300, and 1900 rpm respectively. From the overall results, B10 and B100 exhibited the most acceptable engine performance properties. The B100 had a higher cetane index than premium diesel, thus showing the most recommendable result for thermal brake efficiency (BTE).

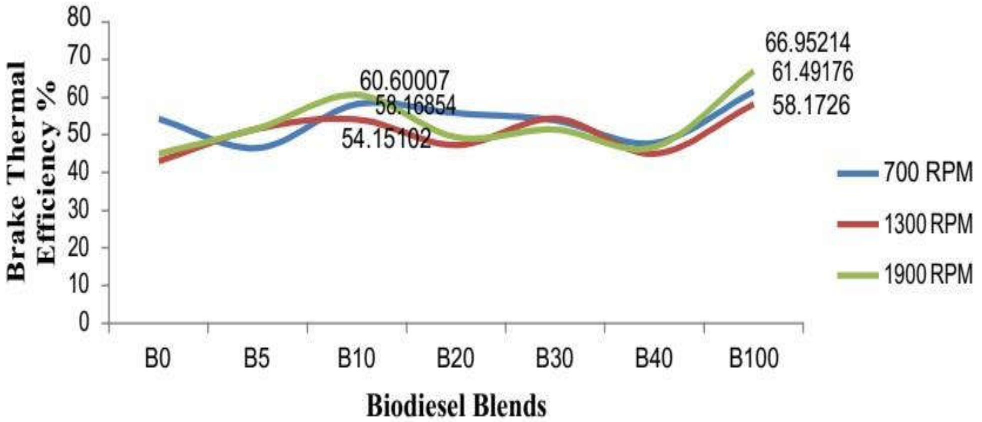

Figure 3: Brake thermal efficiencies of different fuel blends at varying speeds

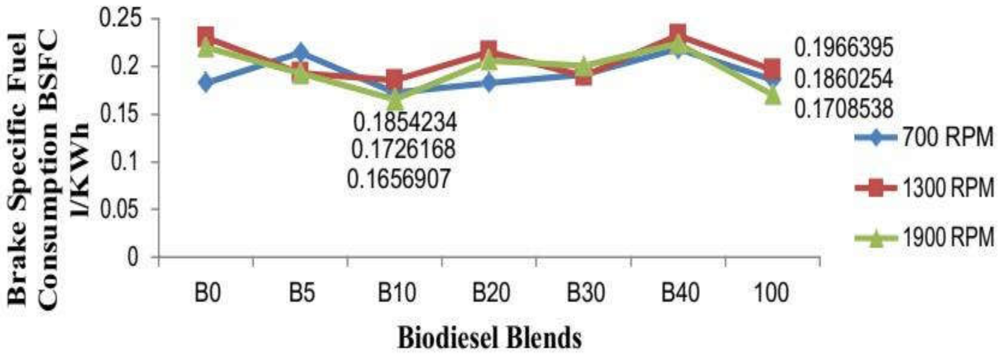

Figure 4: Brake-specific fuel consumption of the different fuel blends

Conclusion

Biodiesel made from palm kernel oil was mixed with premium diesel and ran on a 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, thermal brake 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.

At a speed of 1900 revolutions per minute, the B100 proved to be the second most acceptable for energy production, consumption rates, brake thermal efficiency, and brake-specific fuel consumption. These figures were 5267.66 joules (J), 3.54E-7 meters per second (m3/s), 66.95 percent, and 0.1708 liters per kilowatt hour, respectively. It is possible to conclude that the diesel fuel mix does not have any unfavorable effects on the engine or diminish its performance of the engine. However, instead, it raises the desired performance index and reduces its destructive impacts on the environment. Finally, because B100 had a higher brake thermal efficiency than B0, it performed significantly better than B0 (BTE). In order to validate the feasibility of employing biodiesel blends as alternatives for fossil diesel, additional engine testing must be conducted at more incredible rotating speeds, testing on biodiesel blends, and emission testing must be conducted. It is essential to conduct fuel tests on biodiesel blends made from Jatropha, benniseed, and algal oil to establish whether their utilization in agricultural processes is feasible.

The findings from the present study underscore the importance of integrating biodiesel as an alternative fuel for premium diesel in Nigeria. Numerous studies have emphasized that the exhaust gas emissions from B100 were far more acceptable than emissions from B0 and other blends. For instance, Al-lwayzy and Yusaf (2017) found that MCP-B100 produces less emission than PD. Statistically significant differences were found in the engine brake power, torque, BSFC, exhaust gas temperature, CO^2, and NOx when MCP-B100 and its blends when compared to PD. Also, Örs et al. (2020) noted that B100 caused an average reduction in brake power and exhaust gas temperature of 15.16% and 1.4%. The results conclude that biodiesel blends can be the best substitute for petroleum diesel.

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