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INVESTIGATING SCHIZIOPHYTON RAUTANENII BIODIESEL AS FUEL FOR THE DIESEL ENGINE

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ABSTRACT
The search for plant kernel oils for use as potential substrates for production of biodiesel continues to draw global attention. In the current paper, the performance and emission characteristics of biodiesel derived from schiziophyton rautanenii kernel oil were investigated in a diesel engine. The parameters investigated are brake thermal efficiency, engine torque, brake power, specific fuel consumption, hydrocarbons, carbon dioxide, carbon monoxide, oxygen and soot production. The results indicate that Schiziophyton rautanenii biodiesel used in this study was comparable to petroleum diesel in terms of performance and emission characteristics, and is recommended for use in diesel engines.

KEY WORDS
Biodiesel, alternative fuel, performance, emissions.

1. Introduction

Biodiesel continues to attract global attention as a suitable alternative to petroleum diesel as diesel engine fuel. For this reason, the search for plant kernel oils for use as feedstock for biodiesel production continues to draw attention world-over. Biodiesel is attractive as an alternative fuel due to its high potential to reduce levels of emissions such as hydrocarbons, carbon monoxide and smoke when used in engines, in addition to being renewable and biodegradable [1; 2]. Although properties of biodiesel derived from numerous plant kernel oil species have been investigated [3], schiziophyton rautanenii kernel oil based biodiesel has not been explored.
The Schiziophyton Rautanenii tree grows up to a height of approximately 20m [4], with a trunk of about 1m thick and branches that form a spreading crown [5]. The schiziophyton rautanenii species grows on sandy soils and alluvial margins of major rivers [6]. It thrives under climatic conditions of 30°C on average and annual rainfall of between 200mm and 1000 mm [6].


(a) Plant and fruits


(b) Dried fruits and seeds


(c) Kernels

Figure 1: Schiziophyton rautanenii

Though Schiziophyton rautanenii kernels are edible, their envisaged potential use as feedstock for biodiesel production is considered an appropriate utilization of a near redundant resource as it is scarcely used for food. This is coupled by its high oil yield of approximately 58.61%, experimentally established by the current work, which is one of the important parameters considered in identifying potential feed stocks for production of biodiesel. This compares well with other conventional feedstock such as jatropha curcas with oil yield of 63.16% [7] and sunflower with oil yield of 39-50% [8].

Numerous experimental studies on properties of biodiesel from different feedstock plants as a suitable replacement for fossil diesel have been performed [9; 10; 11]. But fuel characteristics of Schiziophyton rautanenii biodiesel seem not to have been explored. The major properties of Schiziophyton biodiesel include calorific value, flash point, cloud point, pour point, specific gravity, acidity, and kinematic viscosity. Table 1 presents selected physico-chemical properties of petroleum diesel and Schiziophyton biodiesel that were experimentally determined in the current work.

Table 1 : Characteristics of biodiesel and petroleum diesel fuels

Diesel fuel	Flash point (° C)	Cloud point (° C)	Pour point (°C)	Calorific value (MJ/kg)	Acid value (mg KOH/g)	FFA (%)	Density (25°C) (kg/m^3)	Kinematic viscosity (40°C) (mm^2/s)
SR100	131	0	-5	41.7	0.33	0.17	817	3.86
PD	79	2	-12	46.5	0.28	0.14	831	2.73

Legend: PD - Petroleum diesel
SR100 - Schiziophyton rautanenii biodiesel

In Table 1, flash point of Schiziophyton rautanenii biodiesel is shown to be high relative to that of petroleum diesel, and is within specifications of ASTM D 93. This implies that the fuel is safe to handle and transport. From the low cloud and pour points of Schiziophyton rautanenii biodiesel fuel, it can be concluded that the fuel has good cold flow properties and is suitable for use in cold climates regions in its natural state. The calorific value of Schiziophyton rautanenii biodiesel is quite comparable to that of petroleum diesel, with a variation of 10.3%. From the experimental values shown in Table 1, acid values of Schiziophyton rautanenii biodiesel and petroleum diesel fuels are within specifications of ASTM D 6751 standard which specifies a maximum of 0.8 mg KOH/g. This suggests that on the ASTM standard, Schiziophyton rautanenii biodiesel fuel can be used in compression ignition engines with insignificant chances of acid attack on engine parts.The specific gravity of Schiziophyton rautanenii biodiesel is high though marginally lower than that of petroleum diesel by 1.6%. A high specific gravity renders a fuel a narrow spray and a deeper penetration. The viscosity of Schiziophyton rautanenii biodiesel falls within range of EN 14214 specification of 3.5 – 5.0 mm^2/s, while that of petroleum diesel falls short of the minimum requirement by 22%. This shows that Schiziophyton rautanenii biodiesel fuel meets fluidity requirements of alternative diesel engine fuel and can therefore be used in diesel engines. However, both petroleum diesel and Schiziophyton biodiesel fuel meet ASTM specification of 1.9 – 6.0 mm^2/s.

The current work experimentally investigates performance and emissions characteristics of Schiziophyton rautanenii biodiesel and petroleum diesel as fuels in a diesel engine. The characteristics investigated are engine torque, fuel consumption, brake power, brake thermal efficiency, unburned hydrocarbons, carbon monoxide, carbon dioxide and oxygen.

2. Experimental Methods

Schiziophyton rautanenii kernels used in this study were harvested in Paje village in Botswana. The village is located approximately 340km north-west of Gaborone city. Kernels were extracted from dry and mature seeds. Oil extraction, biodiesel preparation, performance tests and emission measurements were performed according to procedures outlined in Gandure and Ketlogetswe [12].

3. Results and Discussions

3.1 Performance Parameters

Performance characteristics evaluated include engine torque, brake power, specific fuel consumption and brake thermal efficiency. Results presented and discussed in this work are for compression ratio 16:1 though experiments were conducted for a wider range of compression ratios. In the experiments, results for Schiziophyton rautanenii biodiesel were compared with those of petroleum diesel measured under similar conditions.

3.1.1 Engine torque

Figure 2 shows the variation of engine torque with engine speed generated by Schiziophyton rautanenii biodiesel and petroleum diesel fuels.

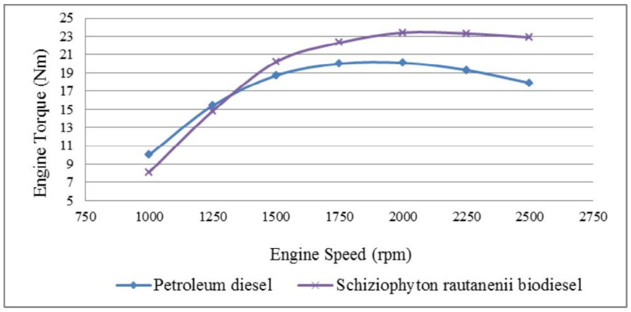

Figure 2: Variation of engine torque with engine speed

The trends in Figure 2 depict that for petroleum diesel and Schiziophyton rautanenii biodiesel fuels, torque gradually increases with increase in engine speed to maximum values of 20.1Nm and 23.4Nm at engine speed of 2000rpm for both fuels, and then decreases to values of 17.9Nm and 22.9Nm respectively at engine speed of 2500rpm. Overall, the biodiesel fuel largely generated higher torque than petroleum diesel at engine speeds higher than 1350rpm. This may be due to superior combustion caused by inbound oxygen and better atomization and spray characteristics for Schiziophyton methyl ester.

3.1.2 Brake power

The variation of brake power with engine speed for the diesel fuels is shown in Figure 3.

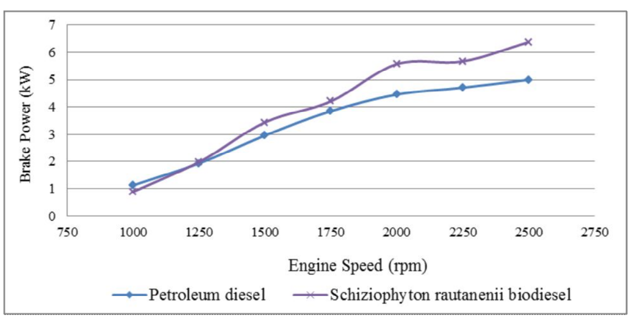

Figure 3: Variation of brake power with engine speed

Brake power is the useful power available at the crank shaft of the engine and its magnitude is dependent on the nature of the fuel. The trends in Figure 3 show that for both petroleum and biodiesel fuels, brake power increases with increase in engine speed. Schiziophyton rautanenii biodiesel fuel largely generated higher brake power than petroleum diesel, except at speeds lower than 1250rpm. This is consistent with the high torque shown in Figure 2. In spite of having lower calorific value than petroleum diesel (Table 1), the engine powered with Schiziophyton rautanenii biodiesel was able to provide better output (brake power) than when powered with petroleum diesel. This is due to a couple of reasons. Firstly, biodiesel fuels have inbound oxygen which provides for better combustion efficiency [13; 14]. Secondly, the biodiesel fuel used in this study had average viscosity of 3.86mm^2/s while petroleum diesel had 2.3mm^2/s at 40^{o}C. This implies higher lubricity for the biodiesel fuel which improves combustion. The effect of atomisation and spray, though comparable, also contribute to better combustion.

3.1.3 Specific fuel consumption

Figure 4 presents the variation of specific fuel consumption (SFC) with engine speed.

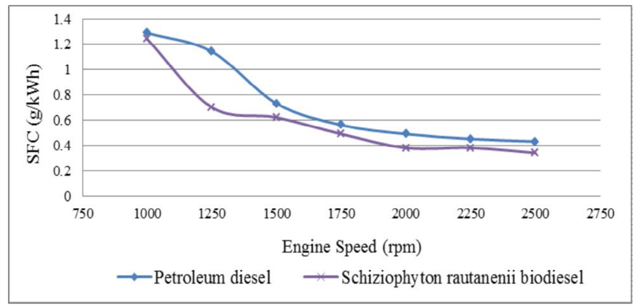

Figure 4: Variation of SFC with engine speed

The fuel consumption profiles presented in Figure 4 show a gradual decrease in consumption with increase in engine speed for both fuels. Petroleum diesel consumption is shown to be higher than that of the biodiesel fuel. These trends may be due to efficient combustion of the biodiesel fuel as a result of the in-bound oxygen, improved lubricity and shorter ignition delay periods. These results are in agreement with findings by Hasimoglu et al [15] who concluded that the use of biodiesel fuel improves specific fuel consumption of a diesel engine.

3.1.4 Brake thermal efficiency

Figure 5 shows the variation of brake thermal efficiency (BTE) with engine speed for petroleum diesel and Schiziophyton rautanenii biodiesel.

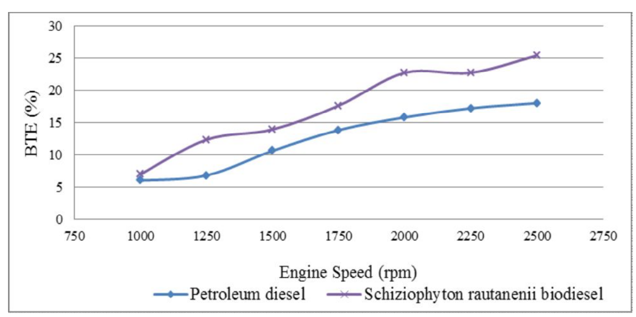

Figure 5: Variation of BTE with engine speed

Brake thermal efficiency is a measure of the overall efficiency of the engine. The trends in Figure 5 show that BTE increases with increase in engine speed, with the biodiesel fuel largely performing better than petroleum diesel. The improved efficiency of the biodiesel fuel is due to its superior combustion discussed in sections 3.1.2 and 3.1.3.

3.2 Emissions Characteristics

The emissions presented in this work are hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2) and oxygen (O_2). Because of the limitations of the instrument used, nitrogen oxides could not be measured consistently and are therefore excluded from the current presentation.

3.2.1 Hydrocarbon emissions

The variation of hydrocarbons emission levels of Schiziophyton rautanenii biodiesel and petroleum diesel fuels with respect to engine speed is presented in Figure 6. The trends show that HC emissions of the biodiesel fuel are much lower than those of petroleum diesel.

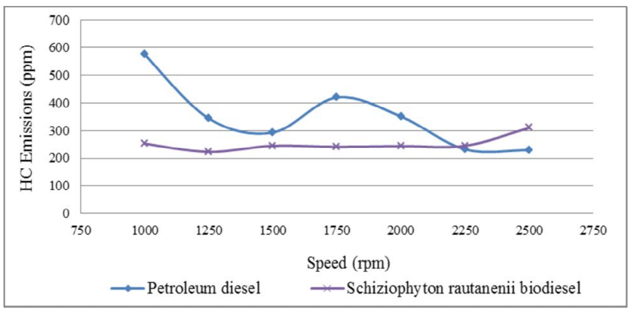

Figure 6: Variation of HC emissions with engine speed

This is consistent with findings by Nabi et al [16] and Som et al [17] who concluded that the use of biodiesel results in lower emissions of carbon monoxide and hydrocarbons. The reduction in hydrocarbon emissions from combustion of the biodiesel fuel could be attributed to the presence of oxygen in the biodiesel that enables more complete combustion. The high HC emissions for petroleum diesel which tend to decrease with increase in engine speed is attributed to lower fuel to air equivalence ratio. This is because at low speed conditions, the fuel to air equivalence ratio approaches 1, so the excess oxygen of the biodiesel fuels is favourable for achieving a more complete combustion through superior evaporation rate.

3.2.2 Carbon monoxide emissions

Figure 7 shows the variation of carbon monoxide (CO) emission levels with engine speed for the two diesel fuels.

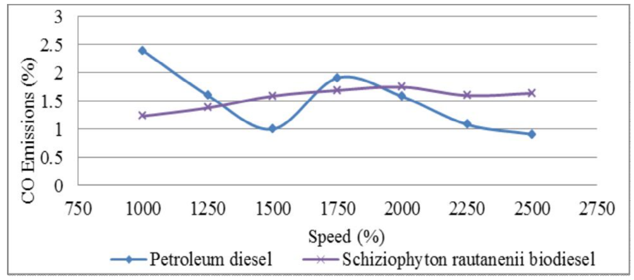

Figure 7: Variation of CO emissions with engine speed

Carbon monoxide emissions of petroleum diesel fluctuate in a decreasing trend while those Schiziophyton rautanenii biodiesel are consistent with little variation across the engine speed range. The stable profile of the biodiesel fuel could be due to improved fuel properties such as viscosity and inbound oxygen which promote combustion and subsequent oxidation of CO to CO_2.

3.2.3 Carbon dioxide emissions

Figure 8 shows the variation of carbon dioxide emission levels with engine speed. Carbon dioxide is the gas that causes the greenhouse effect, which in turn causes climate change. It is therefore imperative to ensure that engine fuel technologies seek to minimise such emissions to mitigate climate change.

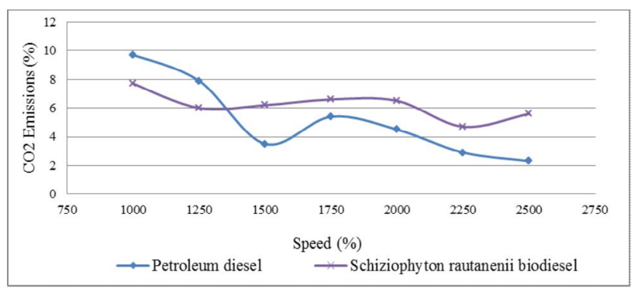

Figure 8: Variation of CO_2 emissions with engine speed

The trends in Figure 9 indicate that CO_2 emissions from the combustion of Schiziophyton rautanenii biodiesel fuel are comparable to those of petroleum diesel, though marginally higher at higher engine speeds. The highest CO_2 emission levels recorded for the biodiesel and petroleum diesel fuels are 7.7% and 9.7% respectively at 1000rpm for both fuels.

3.2.4 Oxygen emissions

Figure 9 presents the variation of oxygen emission levels with engine speed. The level of oxygen emission is simply an indication of whether or not the engine was starved of oxygen for combustion during the power stroke. A higher level of O_2 emissions indicates that the engine had surplus oxygen for combustion, and a low proportion indicates a near oxygen starvation which impacts combustion efficiency. Oxygen emission profiles shown in Figure 9 indicate comparable emission levels for petroleum and Schiziophyton rautanenii biodiesel fuels.

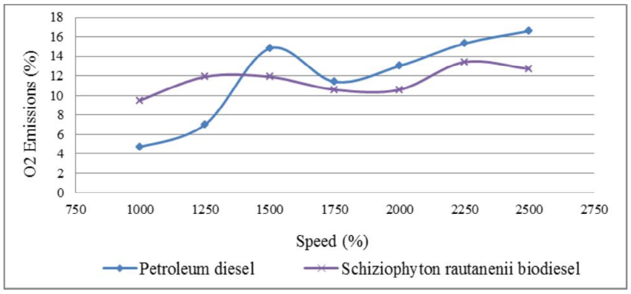

Figure 9: Variation of O_2 emissions with engine speed

3.3 Soot Production

During engine performance analysis, the smoke produced from the combustion of petroleum diesel was observed to have higher opacity when compared with that from combustion of Schiziophyton rautanenii biodiesel. This was confirmed by measurements of soot produced during combustion of the two fuels in a bomb calorimeter where the crucibles used for the tests were weighed before and after each test run. Soot produced from combustion of 3ml of each fuel is presented in Figure 10.

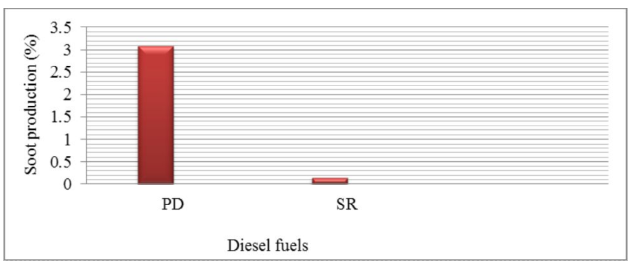

Figure 10: Soot production

Results presented in Figure 10 show that combustion of 3ml of petroleum diesel (PD) produces soot that is significantly higher than that produced from combustion of Schiziophyton rautanenii biodiesel, in the orders of approximately 3.1% and 0.15% respectively. These findings indicate that Schiziophyton rautanenii biodiesel is a clean fuel that contributes insignificantly to environmental pollution. The results of soot production analysis are consistent with observations made by Graboski *et al.*, [18] that using biodiesel fuel to power internal combustion engines reduces emissions of HC's and CO.

4. Conclusion

From the work presented in this manuscript, the conclusions summarised below can be made.

(i) Schiziophyton rautanenii biodiesel depicted superior performance in a diesel engine than petroleum diesel in terms of engine torque, brake power, specific fuel consumption and brake thermal efficiency.

(ii) The level of HC emissions produced from combustion of Schiziophyton rautanenii biodiesel was shown to emit lower hydrocarbon levels than petroleum diesel.

(iii) Emissions of carbon monoxide, carbon dioxide and oxygen were comparable for the two diesel fuels.

(iv) Soot production from combustion of petroleum diesel was found to be significantly higher than that of Schiziophyton rautanenii biodiesel. This demonstrates that Schiziophyton rautanenii biodiesel is a clean burning fuel with insignificant contribution to environmental pollution.

(v) Overall, results presented in this study show that Schiziophyton rautanenii biodiesel is a suitable substitute for petroleum diesel in terms of fuel characteristics discussed in this work.

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