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Diesel Engine Performance and Emission Properties using Kariya Biodiesel

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Summary — **This study evaluated diesel engine performance and emission properties when fuelled with an already-produced kariya oil biodiesel (KOB) and KOB blends. This intends to explore KOB blends as a supplement in diesel engines. A hand-held exhaust gas analyzer was used to determine the gas emitted. In contrast, the brake power and exhaust gas temperature were determined using a Schenck W230 Eddy Current dynamometer and a thermometer respectively during the operation of the diesel engine fuelled with KOB. In contrast with standard petroleum-based diesel, the findings show that using KOB in diesel engines reduces CO and HC but increases NOx emitted due to its oxygenating property that aids fuel combustion. Also, with an increase in biodiesel blends, the fuel consumption increased, while the brake power and exhaust gas temperature decreased due to lower calorific value, higher viscosity, higher volumetric fuel per engine stroke, and the oxygen content dominating over lower calorific value for better combustion. From the study, both KOB B10 and B30 blends were considered optimally appropriate fuel supplements in a diesel engine. This study presents a proper way to manage the waste from kariya tree using it as a feedstock for biofuel production and diversifying different seeds through which biofuel can be produced.**

Keywords — **Biofuel, trans-esterification, bio-catalyst, exhaust gases, engines, emission properties**

I. Introduction

Biodiesel is produced via transesterification of vegetable oil or animal fat mixed with alcohol and a catalyst. Studies show that vegetable oil is a potential fuel in diesel engines due to its simple production process, ecologically friendliness, and similar physiochemical properties to petroleum-based diesel. However, it affects the durability of a diesel engine negatively when used directly. This is due to its high viscosity which thickens its oil lubricant and increases fuel droplets in the engine cylinder thereby leading to partial fuel combustion, excessive carbon build-up, and blockage of the combustion chamber [1]-[3]. To provide solutions to these challenges, some diesel engines were improved to heat the oil before its injection to enhance its atomization in the combustion chamber. Also, different research on the use of oil mixed with petroleum-based diesel as a supplementary fuel in diesel engines has been carried out. However, this blend only reduces the challenges but never eradicate them which make transesterification of vegetable oil needed before blending it with petroleum-diesel. Biodiesel produced through this process is then mixed with petroleum-based diesel to enhance its use in a diesel engine and to conform to the ASTM quality standard.

It is important to note that the use of edible oil seeds in biodiesel production constitutes a direct competition with their usage as food resulting in a reduction in food supply. Due to these limitations, unconventional oil seeds and wastes are being explored as feedstock in biodiesel production. Africa has great potential for biodiesel production based on its widespread diverse oil seed plants which are major feedstock for its production. Some of these oil-seeds already studied include: Luffa aegyptiaca Mill [4], [5], Ricinus communis [6], [7], Azadirachta indica [8], Jatropha curcas [9], [10] and Hevea brasiliensis [11]. And some unconventional oil-seeds which are non-edible but are good feedstock potential in producing biofuels include Delonix regia, Cypripedium acaule, Asclepias syriaca, Millettia pinnata, Sapindus mukorossi, and Helianthus annuus [12]-[14].

[15] studied the performance characteristics like; brake thermal efficiency, torque, fuel used, and power output of an internal combustion engine when fuelled with some biodiesel. It was discovered that biodiesels contain about 10 percent weight of oxygen. This oxygen enhances fuel combustion, yet it increases the amount of fuel consumed when the engine is in operation. The blends of Jatropha oil biodiesel with petroleum-based diesel gave a better brake thermal efficiency which rises from 27.4% to 28.7% [15].

Contrarily, [16] investigated sunflower, safflower, and rapeseed oil biodiesel fuel in diesel engines, and the power output was discovered to be similar to the power output of petroleum-based diesel but durability challenges were predicted as a result of the carbonizing effect. [17] investigate the effect of varied engine speeds at full and partial loads of a diesel engine comparing sunflower oil biodiesel with petroleum-based diesel as fuel during the operation. It was observed that sunflower biodiesel had a lower brake power and higher fuel consumption when compared with petroleum-based diesel. Nevertheless, biodiesel is preferred to petroleum-based diesel based on its lubricant properties which help the lifespan of the engine. Being an oxygenated fuel, biodiesel produces lower greenhouse gas emissions in a diesel engine than petroleum-based diesel.

Moreover, biodiesel is referred to as clean fuel because there is no production of SO_x and CO_2 in its emission during use. [18] evaluated the performance of tobacco seed oil biodiesel in a diesel engine and observed a rise in torque and power (having a lesser heating value of 39.8MJ/kg). Several experiments were carried out for indirect injection of biodiesel blends in diesel engines with

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1500 and 3000rpm engine speeds. Despite the lower heating value that was observed with the use of biodiesel, the highest torque and power were observed when a 17.5 percent blend was used. An investigation was carried out by [19] to examine differently oxidized soybean oil biodiesel. The fuel consumption of pure, oxidized, and non-oxidized biodiesel increased to 15.1, 12, and 13.8 % respectively. The variation in the fuel consumed is attributed to the varied heating values of the biodiesels. [20] investigated linseed oil biodiesel performance in a diesel engine. In the research, an increase in thermal efficiency was observed particularly at lower loads.

In contrast, [21] observed a reduction in diesel engine efficiency when fueled with palm oil biodiesel of 0% and 20% blends, however, the slight variation (less than 2.3 percent in both cases) could be significant. It was also discovered that there was an increase in energy consumption. It was discovered that there was a power reduction at full load of the diesel engine at low speed and high speed of 5% to 10% reduction respectively [22].

Kariya seed oil has been found to be non-edible making it suitable for biodiesel production as it does not compete with human consumption [23]. The biodiesel produced from kariya seed oil has been found to be a good potential fuel to supplement petroleum-diesel in an internal combustion engine due to its fuel characteristics [24], yet the performance evaluation with emission properties of the engine while fuelled with this biodiesel is yet to be investigated in any literature. This study presents a proper way to manage the waste from kariya trees using it as a feedstock for biofuel production and diversifying different seeds through which biofuel can be produced.

II. Materials and Methods

The performance evaluation (fuel consumption, brake power, and exhaust gas temperature) of a diesel engine (Nulux R175A Diesel Engine) fuelled with KOB and its blends were determined. The performance of the diesel engine was examined using petroleum-based diesel (B0), prepared kariya biodiesel blends; B10 (10% biodiesel, 90% petrol diesel), B30 (30% biodiesel, 70% petrol diesel), B50 (50% biodiesel, 50% petrol diesel), B70 (70% biodiesel, 30% petrol diesel), and B90 (90% biodiesel, 10% petrol diesel), and biodiesel (B100) [24]. The brake power and the exhaust gas temperature were determined during operation using a Schenck W230 Eddy Current dynamometer and a thermometer respectively. Using a hand-held exhaust gas analyzer (Product Model: Aeroqual Series 500), emission characteristics also were determined; the rate of carbon monoxide, NOx, and hydrocarbon emissions. The results obtained when KOB blends were used were compared with that of pure petroleum-based diesel (B0).

III. Result and Discussion

The result obtained from the diesel engine performance when fueled with biodiesel blends revealed the behavior of each blend when used as fuel and it showed the appropriate blends for a diesel engine.

A. *Emission characteristics*

The emission characteristics result obtained when fueled with the produced KOB blend is shown in Fig. 1(a-c).

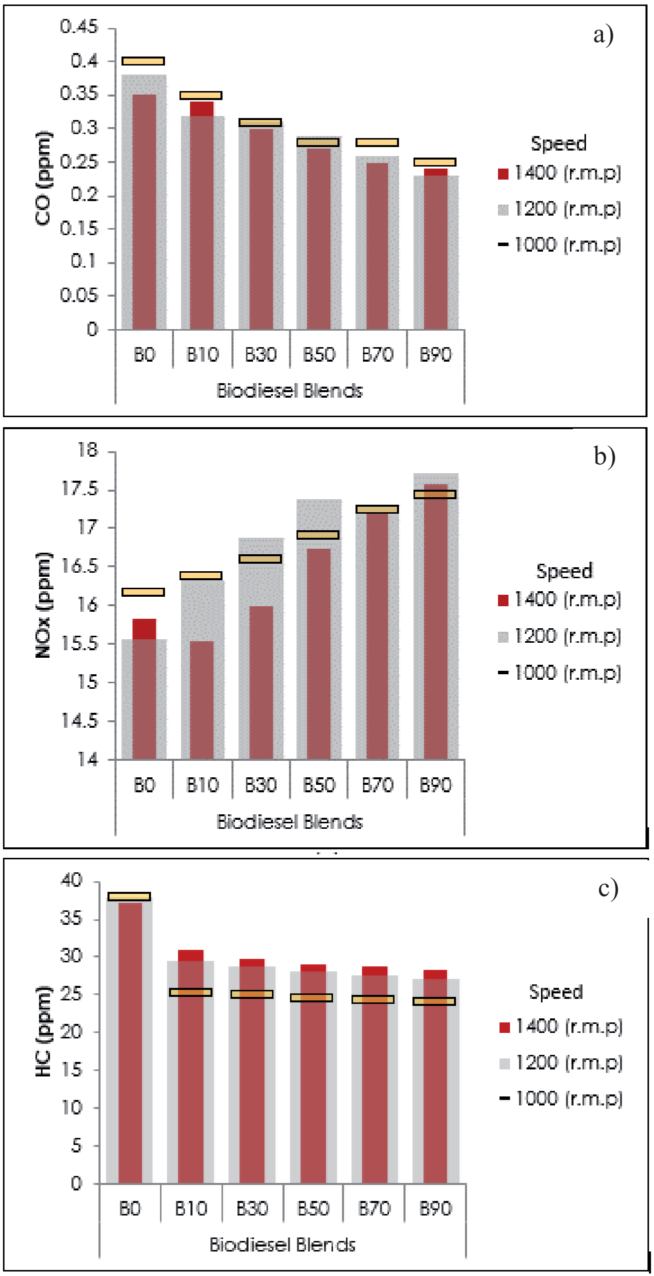

Fig. 1. Exhaust gas analysis vs. the biodiesel blends a) CO b) NOx c) HC

Figure 1a reveals that the carbon monoxide (CO) decreases as the biodiesel blends increase. A little increase in CO emitted was noticed with an increase in the engine speed. As the diesel engine operates at 1000 rpm, the CO emitted was reduced from 0.35 – 0.25, at 1200 rpm, the CO emitted was reduced from 0.32 – 0.23, and at 1400 rpm, the CO emitted was reduced from 0.34 – 0.24. It was observed that when petroleum-based diesel was used the CO emitted was higher than when biodiesel blends were used. The high cetane content and presence of oxygen in the biodiesel's molecular structure can be the cause for the drop in CO emissions that occur as the blend increases. This result implies that since the biodiesel produced contains some oxygen, it aids in fuel combustion, leading to a reduction in CO emitted.

The emission characteristics as shown in Fig. 1b show that the increase of biodiesel blends slightly increases the emission of NOx from 16.38 – 17.44 ppm for 1000 rpm, 16.34 – 17.71 ppm for 1200 rpm, and 15.55 – 17.58 ppm for 1400 rpm. However, there is a random variation of NOx emission through the biodiesel blends as the engine speed increases. The NOx emitted when fueled with petroleum-based diesel at all engine speeds is lower than NOx emitted

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by all the biodiesel blends except at the speed of 1400 rpm when the B10 blend is lower than that of petroleum-based diesel. This result agrees with the findings of previous research on the effect of biodiesel on the NOx emissions which indicate a slight increase in NOx emitted when the biodiesel increases in the blend [19]. Some studies reveal no significant difference in NOx emitted when biodiesel increases in the blend. According to [8], the presence of monomers and polymers of unsaturated fatty acids in biodiesel can be the cause of an increase in NOx emitted. It can also be attributed to the presence of oxygen in the biodiesel which results in NOx formation that is majorly initiated by high cylinder temperature with its occurrence crank angle.

The result in Fig. 1c showed that hydrocarbon emitted by the engine decreases with the increase of biodiesel in the blend but increases with an increase in engine speed. It was discovered that the hydrocarbon emitted when petroleum-based diesel (B0) was used as fuel in the diesel engine was more compared to when biodiesel blends were used. The decrease in hydrocarbon emitted with an increase in biodiesel blends can also be attributed to the low viscosity and the oxygen content in the biodiesel produced leading to better combustion of the fuel. The increase in the hydrocarbon emitted when the engine speed increases may be associated with the increasing fuel quantity injected into the engine cylinder resulting in the fuel incomplete combustion thereby increasing hydrocarbon emitted. A similar trend was also observed with decreasing CO and HC and increasing NOx while operating the diesel engine with biodiesel produced using castor oil, soybean oil, rapeseed oil, sunflower oil, and olive oil ([1], [25], [14], [26]). Conversely, the NOx emitted decreased as the biodiesel increased in the blends when karanja oil, neem oil, jatropha, and sesame oil were tested in a diesel engine though a trend of decrease in CO and HC was observed [27].

B. Performance evaluation

From Fig. 2a, it was observed that the fuel consumed by the engine increased as biodiesel increased in the blends between B10 and B90 from 243.53 – 250.08 g/kWh, 245.88 – 249.85 g/kWh, and 247.10 – 250.35 g/kWh for 1000, 1200, and 1400 rpm respectively. Also, it was observed that the fuel consumed by the engine increases as the engine speed increases except for a slight difference with B30 and B90. This increase may be attributed to the high quantity of fuel introduced into the engine cylinder. It was also discovered that the fuel consumed when KOB was used increased as the blend increased due to the lower calorific value, higher viscosity, and higher volumetric fuel delivery of KOB per engine stroke.

Figure 2b shows the relationship between the brake power and the biodiesel blend ratio concerning the engine speed. At an increasing profile of the blends in the biodiesel for 1000rpm, 1200rpm, and 1400rpm, the brake power of the engine decreases. From the result, there is no substantial difference between the brake power of petroleum-based diesel and B10 of the biodiesel blend. [28] explained that the decrease in the engine brake power as biodiesel increases in the blends can be because of the lower heating value of the biodiesel. A similar trend was observed for biodiesel obtained from corn oil, rapeseed oil, soybean oil, and sunflower oil [29].

The graphical relationship between the exhaust gas temperature and the biodiesel blends concerning engine speed is shown in Fig. 2c. From the result, it was discovered that at an engine speed of 1000 and 1400 rpm, the Exhaust gas temperature decreases from 104.25 – 99.07 °C, 109.98 – 104.23 °C respectively with an increase of biodiesel in the blends from B10 to B90 while at engine speed 1200 rpm, the exhaust gas initially drops at B10 and then rise at B30 and finally decrease as the biodiesel increase. The temperature of the exhaust gas emitted by petroleum-based diesel (B0)

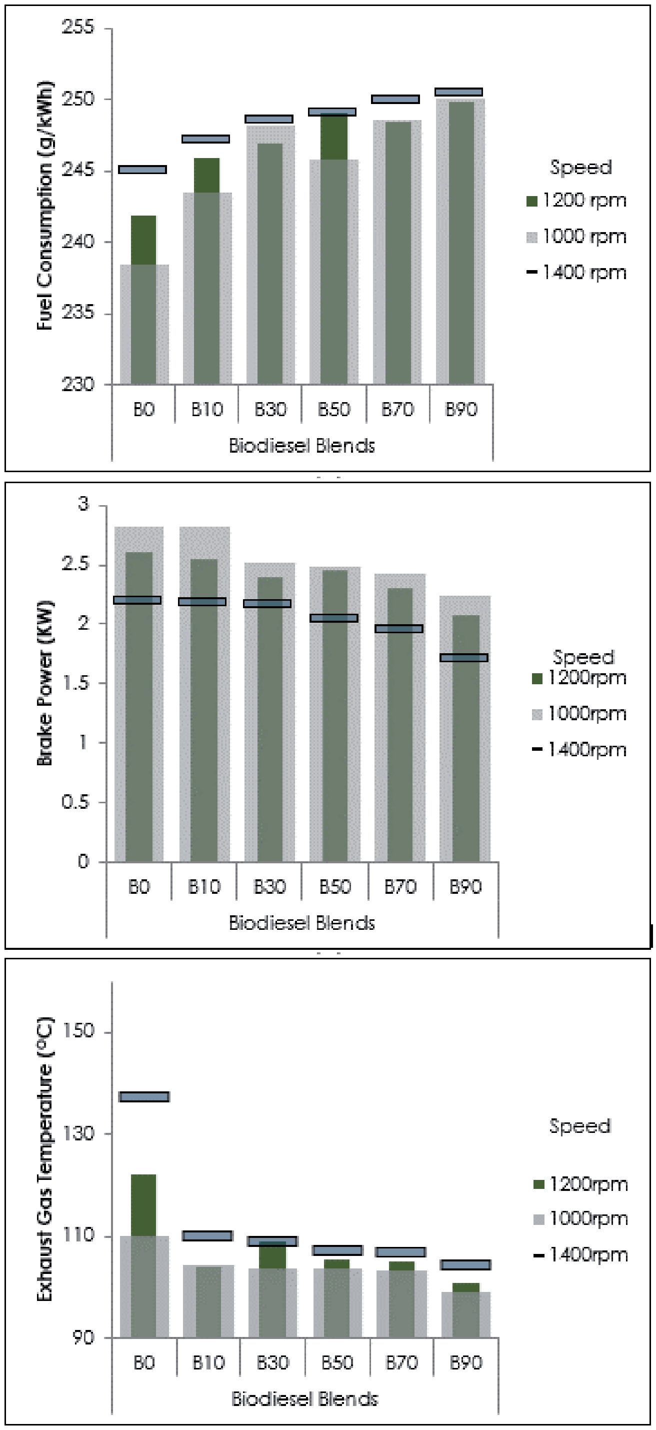

Fig. 2. Engine performance evaluation vs. the biodiesel blends: (a)Fuel Consumption (b) Brake Power
(c) Exhaust Gas Temperature

is higher compared to biodiesel blends and this indicates that in biodiesel, there is complete combustion that has taken place in the engine cylinder converting energy from the fuel to maximum useful work compared to petroleum-based diesel. There is an increase in the exhaust gas temperature when the speed increases because more fuel has been released into the cylinder and there is more combustion of the fuel which produces heat.

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IV. Conclusion

When a diesel engine was fueled with kariya diesel blends, there was a reduction in the emission of CO and HC as biodiesel increased in the blends, however, there was a little more NOx emitted when biodiesel blends were used compared to when petroleum-based diesel was used. Also, the fuel consumed increases as biodiesel increases in the blends while the brake power and exhaust gas temperature are lesser when biodiesel is used compared to petroleum-based diesel. The oxygen content and low viscosity of the biodiesel produced aid complete fuel combustion thereby reducing the CO and HC emitted while increasing the NOx emitted. Also, the oxygen content with a lower calorific value of the biodiesel results in more fuel consumed compared to when petroleum-based diesel was used. The decrease in engine brake power as the biodiesel increases in the blend may be due to the lower heating value of biodiesel. It was noted that there was a decrease in exhaust gas temperature when the biodiesel increased in the blend because of the physicochemical properties of the fuel and the level of oxygen present in it. Based on these findings showing reduced NOx emitted and low fuel consumption, two of the blends of the kariya biodiesel produced i.e. B10 and B30 were more appropriate for use optimally in a diesel engine. For further study on this research, the result of the emission characteristics and the performance evaluation of the engine when fueled with KOB and its blends should be compared with the performance of the engine when fueled with another biodiesel.

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