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Emission Properties of a Diesel Engine Fuelled with Snake Gourd Biodiesel and Blends

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ABSTRACT

In this study, snake gourd biodiesel (SGB) was used as an alternative fuel in a four-stroke, one-cylinder, direct injection, 14.7 kW diesel engine. A test was carried out in which the engine was fuelled with petroleum diesel, SGB and five different blends of diesel/biodiesel (B10, B20, B30, B50 and B80). The test engine was run at 0 kW load and 12.3 kW load, and the results were analyzed. The biodiesel and its blends produced significantly less emissions than the petroleum diesel, which could be attributed to better combustion efficiency. The use of biodiesel resulted in lower emissions of CO, SO_2, particulate matter (PM) and increased emissions of NO_2. The results also showed that increasing the load from 0 kW to 12.3 kW resulted to an overall increase in the emissions and CO, SO_2, and PM emissions were lower with SGB by 86.6%, 93.02%, and 91.80% at 0 kW load and 62.48%, 86.79%, and 72.72% at 12.3 kW load conditions. while NO_2 emissions were higher by 90.91% and 93.02% at 0 kW and 12.3 kW load conditions respectively than that of the petrol diesel. This study showed that the exhaust emissions of SGB and its blends are lower than those of the petrol diesels, which indicates that SGB and its blends when used in diesel engines has more favorable effects on air quality.

Keywords: Snake Gourd, Biodiesel, Emissions, Carbon Monoxide, Sulfur (ii) Oxide, Particulate Matter, Nitrogen Oxide.

INTRODUCTION

The depletion of world's petroleum sources and increased environmental concerns has stimulated recent interest in alternative sources for petroleum-based fuels (Nyishember, 2023). Vegetable oil esters are receiving increasing attention as a non-toxic, biodegradable, and renewable alternative diesel fuel. These esters have become known as biodiesel. Biodiesel produced from vegetable oil or animal fats by transesterification with alcohol like methanol and ethanol is recommended for use as a substitute for petroleum-based diesel mainly because biodiesel is an oxygenated, renewable, biodegradable and environmentally friendly bio-fuel with similar flow performance and low emission profile (Hadiza *et al.*, 2020). The snake gourd oil has been classified as waste, while its potential as a liquid fuel through physical and chemical conversion remains of high interest. It is increasingly attracting much interest because of its great potential to be used as a diesel substitute through transesterification (Adeniyi and Isiaka, 2013). other advantages of biodiesel are; safety, portability, high heat content (about 88% of diesel fuel), better lubrication abilities, lower sulphur and aromatic content (Awulu *et al.,* 2015). Experience has shown that vegetable oil-based fuels can significantly reduce exhaust gas emissions, including carbon monoxide (CO), carbon dioxide (CO_2), and particulate matter (PM) (Cheung *et al.,* 2015). Because of their low sulfur content, they reduce the government burden in waste disposal, maintenance of public sewers and oily wastewater treatment significantly (Hadiza *et al.,* 2020). Furthermore, biodiesel fuel has been shown to be successfully produced from snake gourd oils by base-catalyzed transesterification process and can be

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considered as alternative fuel in diesel engines and other uses (Do˘gan 2016).

The performance and smoke results obtained from an engine used for generating electricity, when fueled with bio-diesels of WCO origin, showed that the smoke reduction was about 60% for B100 and approximately 25% for B20 (Ghannam et al.,2016). Dorado *et al.,* (2003) used waste olive oil in a four-stroke, three-cylinder, 2.5 L direct injection engine with a power rating of 34 kW through an eight-mode test. They achieved 58.9% reduction in CO, 8.6% reduction in CO_2 and 57.7% reduction in SO_2 emissions. On the other hand, increases of 32 and 8.5% in the NOx emissions and specific fuel consumption were observed in the B100 and B20 mixtures, respectively. Murillo *et al.,* (2007) tested a four-stroke diesel outboard engine running on conventional diesel, conventional diesel blended with certain amounts of WCO bio-diesel (10, 30 and 50%), and pure bio-diesel and proved that the bio-diesel blends are environmentally friendly alternatives to conventional diesel. They also found some reduction in power of approximately 5% with B10 and B30, and 8% with B50 and B100 with respect to the power obtained from conventional diesel. Prakash *et al.,* (2006) investigated the performance and emission characteristics of Karanja oil using different biodiesel blends with diesel fuel. The results indicated that 20% blend of karanja methyl ester showed better performance characteristics compared to other blends. Furthermore, it was illustrated that the exhaust emissions such as PM and smoke density decrease with blend while the NOx was slightly increased. In another study, wasted cooking oil from restaurants was used to produce neat (pure) biodiesel through transesterification, and this converted biodiesel was then used to prepare biodiesel/diesel blends (Peng et al., 2018).

In this study, the emission properties of a diesel engine fuelled with snake gourd biodiesel (SGB) (B100) and blends (B10, B20, B30, B50, B80) was investigated and compared with that of petroleum diesel (B0) in a four stroke, one-cylinder direct-injection diesel engine under 0 kW load and 12.3 kW load conditions.

MATERIALS AND METHODS

Materials used were snake gourd oil, methanol, potassium hydroxide (KOH) as catalyst and other laboratory reactants and apparatus.

Production of Snake Gourd Biodiesel and Characterization

Production of the snake gourd biodiesel was done in the analytical chemistry laboratory, Joseph Sarwuan Tarka University (JOSTUM). 500 ml of filtered and dried oil was measured into a beaker (reaction vessel) which was maintained at 50^oC to improve the oil’s miscibility with the alcohol. 2% m/m of potassium hydroxide pellets was weighed and completely dissolved in 100 ml methanol. The mixture was added to the oil in the reactor vessel and the entire content brought to a temperature of 60^oC. This mixture was maintained at this temperature for 30 minutes with consistent mixing/stirring speed of 600 rpm in reactor vessel.

After 30 minutes, the mixture was transferred into a separating funnel and left-over night for good separation of the denser glycerin phase at the bottom and lighter biodiesel phase at the top. The glycerin was drained off into a beaker and the biodiesel retained in the flask. The retained biodiesel was transferred into a beaker, washed with warm water and placed in the oven at 105^oC for 1hour to remove all traces of water. This process was repeated until 5 liters of SGB was obtained.

The characterization of the snake gourd oil and snake gourd biodiesel was done in accordance with AOAC and ASTM standard methods of analysis. The specific gravity and density were measured using specific gravity bottle, kinematic viscosity was measured (ASTM D445) using a viscometer, refractive index was measured with the means of a refractometer, and pH with a pH meter.

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Blending

The diesel was then blended with petroleum diesel with various percentages such 10% (B10), 20% (B20), 30% (B30), 50% (B50), and 80% (B80).

Determination of Emitted Gases

The emission performance of the snake gourd biodiesel and its blends was done on a VIKING SUPER ZS1110NM diesel engine mounted on a steady bed. The engine specifications are shown in Table 1. A short trial was done to ensure that the engine and other experimental components were in working order and allowed to warmed up with the petroleum diesel before switching to the various diesel blends. Three single digital gas analyzers (Crowncon CO gas detector, NO_2 gas detector, SO_2 gas detector), and a particulate monitor, were placed at the exhaust of the engine to read values of emitted gases (CO, NO_2, SO_2, and PM) from the exhaust of the engine for each blend at intervals of 10 minutes while varying loads of 0 kW and 12.3 kW respectively. After each individual tests with SGB blends, the engine was always switched off and readings recorded. The constant load used for the test was a single phase Toshon ARC 400 inverter welding machine with a rated power of 12.3 kW

Table 1: Engine Specifications

Parameters	Description
Model	VIKING SUPER ZS1110NM
Engine type	One-cylinder, horizontal, four stroke
Combustion system	Direct injection
Bore (mm)	110
Stroke (mm)	115
Displacement (l)	1.093
Power output (kW)	14.7
Engine speed (RPM)	2200
Compression Ratio	17:1
Fuel consumption (g/kW.h)	< 244.8
Cooling method	Water-cooled
Lubrication method	Combined pressure and splash
Starting method	Hand starting
Net weight (kg)	185

RESULTS AND DISCUSSIONS

Results

The results of the fuel properties of the SGB are represented in Table 2. Table 3 shows data of the emissions from a diesel engine fuelled with B100, B0 and blends while Table 4 shows the percentage reduction and increase of emisions using SGB and blends. Figure 1, 2, 3, and 4 shows the CO, NO_2, SO_2, and PM emissions of diesel fuel, SGB and blends at different loads respectively.

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Table 2: Fuel Properties of SGB

Physiochemical Properties	SGB
Water content (%)	0.76
Refractive Index	1.37
Density (kg/m^3)	870.95
Specific gravity @ 25 C	0.88
Kinematic viscosity @ 40 C (mm^2/s)	0.26
pH	7.97
Iodine value (gI_2/100g)	2.97
Peroxide value (meq/kg)	4.56
Flash point (C)	221.33
Fire point (C)	255.33
Cloud point (C)	3.67
Pour point (C)	0.33
Melting point (C)	1.30
Boiling point (C)	125.00
Cetane number	84.60

Table 3: Emission from Engie Fueled with various Blends of SGB and Diesel at Engine Load of 0 kW and 12.3 kW

Emission	Load (kW)	Blends (%)						
		B0	B10	B20	B30	B50	B80	B100
CO (ppm)	0	5.00	4.33	4.00	3.00	2.33	1.67	0.67
	12.3	5.33	4.33	3.67	3.33	2.67	2.33	2.00
NO_2 (ppm)	0	0.03	0.10	0.17	0.20	0.23	0.30	0.33
	12.3	0.10	0.13	0.20	0.23	0.27	0.30	0.37
SO_2 (ppm)	0	0.43	0.33	0.27	0.17	0.10	0.07	0.03
	12.3	0.53	0.50	0.47	0.37	0.30	0.17	0.07
PM (**μm**)	0	17.93	17.10	17.03	16.40	10.13	3.53	1.47
	12.3	17.97	17.67	17.10	16.30	10.40	5.30	4.90

Table 4: Percentage Reduction and Increase of Emisions using SGB and Blends

Emissions	Load	Blends					
		B10	B20	B30	B50	B80	B100
CO (ppm)	0 kW	13.4	20	40	53.4	66.6	86.6
	12.3 kW	18.76	31.14	37.52	49.91	56.29	62.48
NO_2 (ppm)	0 kW	-70	- 82.35	-85.0	- 86.95	-90	- 90.91
	12.3 kW	-23.8	-50	- 56.52	- 62.96	- 66.67	- 72.79
SO_2 (ppm)	0 kW	23.26	37.21	60.47	76.74	83.72	93.02
	12.3 kW	5.66	11.21	30.19	43.40	67.92	86.79

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PM (μm)	0 kW	4.63	5.02	10.54	43.50	80.31	91.80
	12.3 kW	1.67	4.84	9.29	42.13	70.51	72.73

The Negative sign indicate no Reduction (increament) in the Emmisions

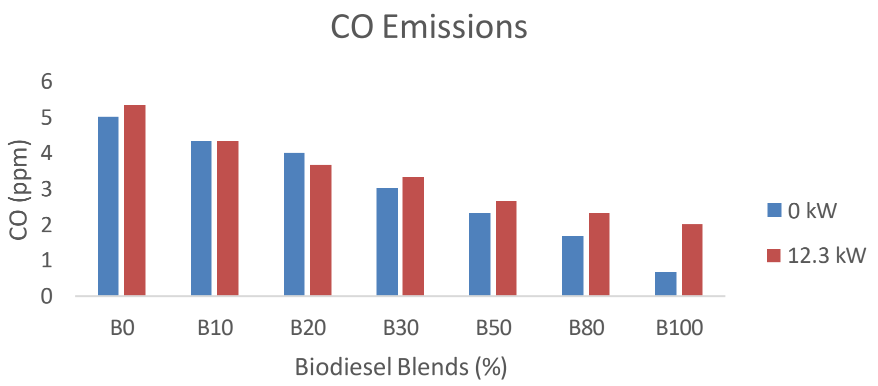

Figure 1: CO Emissions of Diesel Fuel, SGB and Blends at Different Loads

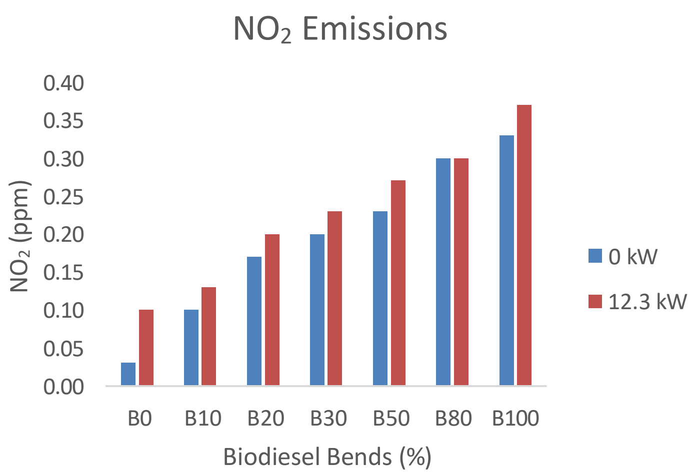

Figure 2: NO_2 Emissions of Diesel Fuel, SGB and Blends at Different Loads

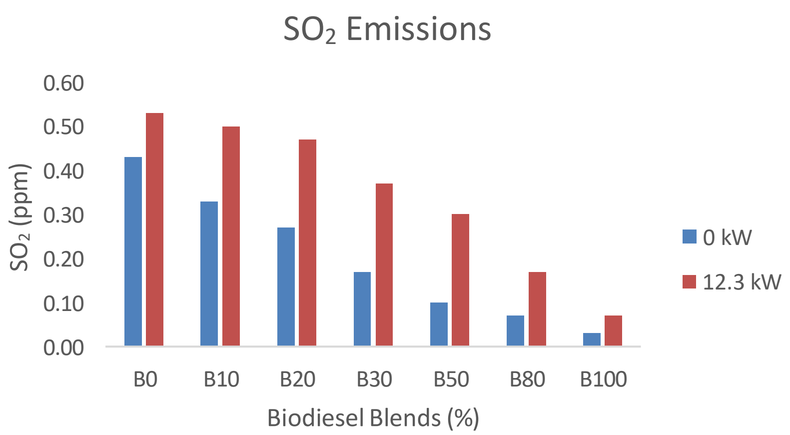

Figure 3: SO_2 Emissions of Diesel Fuel, SGB and Blends at Different Loads

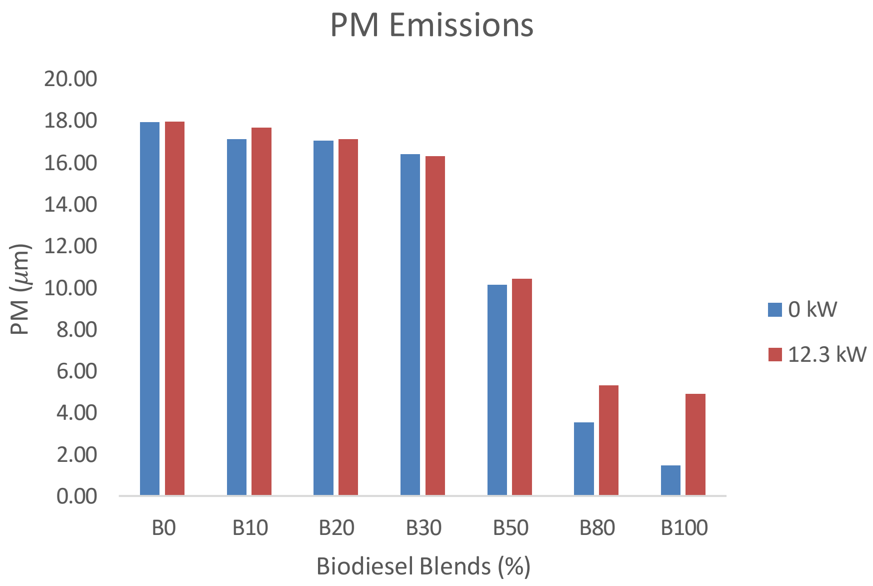

Figure 4: Particulate Emissions of Diesel Fuel, SGB and Blends at Different Loads

DISCUSSION

Table 3 shows the engine emissions of the SGB (B100), biodiesel blends and diesel (B0) at 0 kW and 12.3 kW. The results shows that CO, SO_2, and PM emissions reduced while NO_2 emissions were increased as higher blends of SGB were used. Palash *et al.,* (2013), Onoh *et al.,* (2018) reported a similar trend for engine emissions of biodiesels and their blends. The results also showed that increasing the engine load from 0 kW to 12.3 kW led to an overall increase in the CO, SO_2, PM, and NO_2 emissions respectively.

Table 4 shows the percentage reduction and increased of emissions using SGB and blends. At 0 kW and 12.3 kW load CO emissions were reduced from 13.4% and 18.76% (B10) to 66.6% and 56.2% (B80) while B100 reduced it by 86.6% and 62.48% respectively. NO_2 emissions were increased from 70% and 23.8% (B10) to 90% and 66.67% (B80) while B100 increased it by 90.91% and 72.79% for 0kW and 12.3 kW loads respectively. The emissions of SO_2 were reduced from 23.26% and 5.66% (B10) to 83.72% and 67.92% (B80) while that of B100 were reduced by 93.0 % and 86.79% respectively for 0kW and 12.3 kW loads. Also, PM emissions were reduced from 4.63% and 1.67% (B10) to 80.31% and 70.51% (B80) for 0 kW and 12.3 kW loads respectively while that of B100 were reduced by 91.80 % and 72.73% for 0 kW and 12.3 kW loads. The results also showed that the emissions were higher at 12.3 kW of load compared to 0 kW load, Vieira da Silva (2017) reported a similar trend for emission characteristics of diesel engine with jatropha biodiesel and its blends.

From Figure 1 it can be seen that SGB blends (B10, B30, B50 and B80) have lower CO emissions for both 0kW and 12.3 kW loads compared to the petroleum diesel (B0) with B100 having the least emissions. The CO emissions decreased from 5.00ppm (B0) to 0.67ppm (B100) and 5.33ppm (B0) to 2.00ppm (B100) at 0 kW and 12.3 kW load respectively. The decrease in CO emissions is due to the presence of high oxygen content in biodiesels, Angelovič *et al.,* (2013) also reported similar observations.

Increasing the engine load to 12.3 kW, increased the CO emission on all the blends when compared to the emissions at 0kW load, this is due to the lower availability of oxygen as a result of the reduction in overall air/fuel ratio (Ramakrishna *et al*., (2013). The highest CO emission was found at engine load of 12.3 kW as 4.33ppm for B10, this value was lower than the CO emission for B0 which was 5.00 ppm when the engine was running at 0 kW load. This is an indication that the SGB has less CO emissions and contributes minimally to global warming.

Figure 2 shows that, the emission of NO_2 in all the blends were increasing with increased SGB blends, this is as a result of high cetane number and oxygen content of the SGB, Jayabal *et al.*, (2020) reported similar observation. Mohamed (2017) also reported that, increase in combustion temperature due to reduced particle emissions decreases the ability to radiate heat in engines, therefore increased NO_2 emissions in biodiesels. Figure 2 also showed that, the emissions were higher at 12.3 kW when compared to the emissions when the engine was operating at 0 kW load.

Figure 3 shows the variation of SO_2 emissions with SGB blends and loads. It indicates that, increasing the SGB blends from B10 to B80 resulted in decreased SO_2 emissions with B100 having the lowest values of 0.07ppm and 0.33ppm for 0 kW and 12.3 kW loads respectively. It is also shows that, increasing the engine load to 12.3 kW loads resulted in an increased in SO_2 emissions in the SGB blends compared to when the engine was running at 0 kW load.

Figure 4 shows particulate emissions of SGB at different loads and blends. The result shows that increasing the percentage of SGB in the blends reduced PM emissions of the engine. This is attributed to the high oxygen content in biodiesels, (Lakshmi *et al.,* 2007). Increasing the engine load from 0 kW to 12.3 kW resulted to an increase in PM emission, this is due to the increased smoke emissions associated with higher engine loads. Gokalp *et al.,* (2011) reported similar observation.

CONCLUSION

The engine emission properties of the biodiesel and its blends showed that the use of SGB and blends in the diesel engine reduced CO, SO_2, and PM emissions while NO_2 emissions increased compared to petroleum diesel. CO, SO_2, and PM emissions were lower with SGB by 86.6%, 93.02%, and 91.80% at 0 kW load and 62.48 %, 86.79%, and 72.72% at 12.3 kW load conditions. while NO_2 emissions were higher by 90.91% and 93.02% at 0 kW and 12.3 kW load conditions respectively than that of the petrol diesel. The engine emissions at 12.3 kW load were higher with SGB and its blends compared to when the engine was running at 0 kW (no-load), this trend was more noticeable in PM emission because of the decrease in air-to-fuel ratio at higher loads leading to more incomplete combustion of the fuel. Hence, SGB and its blends can be used in diesel engines without modifications having to be made to the engines and its blends reduced CO, SO_2, and PM emissions from a diesel-fuelled engine, making it more environmentally friendly as compared to petroleum diesel.

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