



## ENGINE PERFORMANCE AND EMISSION ANALYSIS OF YELLOW OLEANDER, RESIDUAL COOKING OIL AND FOSSIL DIESEL

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### ABSTRACT

Engine performance and emission characteristics of biodiesel produced from yellow oleander, soyabeans residual cooking oil and fossil diesel was carried out in a compression ignition engine. The engine was operated at constant speed of 2160rpm and variable torque (4, 7.5 and 10.6Nm). The oil extracted from yellow oleander by mechanical press had a yield of 60%. Physicochemical properties of the oil were determined. The chemical composition of the biodiesels was analyzed and the result revealed that yellow oleander and soyabeans residual cooking oils contain 86.2% and 85.3% methyl esters respectively. The engine performance tests of the yellow oleander, soyabeans residual cooking oil and fossil diesel at a constant speed 2160rpm and variable torque (4, 7.5 and 10.6Nm), were found to be 2.40kw, 1.70kw and 0.91kw for brake power and 51412.57 MN/m<sup>2</sup>, 36376.87 MN/m<sup>2</sup> and 19401.02 MN/m<sup>2</sup> for brake mean effective pressure respectively. Similarly, at constant speed of 2160 rpm and variable torque (4, 7.5 and 10.6Nm), it was also found that in comparison to fossil diesel fuel, the emission reduction for soyabean residual cooking oil biodiesel at engine torque of 4Nm was 67% for CO, 47% for CO<sub>2</sub>, 100% for HC and 40% increase for NO<sub>x</sub>. However, there was no remarkable change in emission reduction when the engine torque was increased from 4 to 10.6Nm at constant engine speed of 2160 rpm. Biodiesel from yellow oleander and residual cooking can be used as part of substitutes for compression ignition engines to reduce the effects of greenhouse gases emissions caused by fossil diesel fuel combustion from heavy duty equipments .

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### 1.0 Introduction

The utilization of fossil fuels has adverse effects on the environment like pollution, global warming and unfavorable climate change (Jaynes, 2010, Batidzirai *et al.*, 2006; Alamu *et al.*, 2008; Gupta *et al.*, 2007). Biodiesel are fuels derived from plants and animal sources and can serve as alternatives to fossil fuels (Rubi *et al.*, 2011, Atadashi *et al.*, 2012). Biodiesel are biodegradable, non-toxic, eco-friendly, provide longer engine life span when used in automobiles (Ibrahim *et al.*, 2014). Due to the depletion of fossil fuel reserves, rising prices and environmental pollution, this has led to renewed interest in biodiesel production. With respect to low cost, waste to energy and non-edible feedstock; residual cooking oil (RCO) and Yellow Oleander (YO) seed has been selected as feedstock for biodiesel production.

In the present study, the performance and emission characteristics of a diesel engine at constant speed and variable torque were investigated while running on Yellow Oleander biodiesel, residual cooking oil biodiesel and pure diesel.

## 2. Materials and method

The materials used for the production of yellow oleander biodiesel and residual cooking oil biodiesel, physicochemical properties tests and engine performance evaluations were locally obtained from Samaru Zaria, Kaduna State. The yellow oleander plant and seeds are shown in Figure 1.



**Figure 1:** Yellow oleander plant and seeds

### 2.1 Methods

#### 2.1.1 Seed Collection and preparation

The seeds of yellow oleander were obtained from aviation quarters Zango, Zaria Kaduna state and the soyabeans residual cooking oil was obtained locally from a fish seller at Hayin Dogo, Samaru Zaria Kaduna state. The seeds were plucked fresh, the fleshes were peeled off and the nuts were sun dried for a period of 8hours to enable easy cracking of the shell. After cracking, the seeds enclosed by the nuts were sundried for seven days and the seeds were crushed and grinded.

#### 2.1.2 Oil Extraction

Oil was extracted from the crushed and grinded yellow oleander seed by mechanical press method at the National Research Institute for Chemical Technology (NARICT) Zaria, Kaduna State.

The seeds were placed in the oil press machine and the oil was extracted mechanically. The expelled oil was filtered using a 0.05mm sieve into a beaker. The difference in the weight of the seed sample before and after the extraction of the oil was taken.

Percentage of yield of the oil was calculated using Equation (1)

$$\% \text{ oil yield} = \frac{\text{weight of the extracted oil}}{\text{weight of sample}} \times 100 \quad (1)$$

### 2.1.3 Production of yellow oleander and residual cooking oil Biodiesel by Transesterification Reaction

Transesterification is one of the common chemical reactions of alcohol with vegetable oils in the presence of catalyst. In this work, methanol was used because of its low cost and availability. This reaction methanol was used to reduce the viscosity of yellow oleander and soybeans residual cooking oil and conversion of the triglycerides into ester. The reaction was done with a methanol to yellow oleander/residual cooking oil molar ratio of in the presence of potassium hydroxide (KOH) as a catalyst according to Jamil et al., (2016) using the equipment presented in Figure 2.

$$\% \text{ Biodiesel yield} = \frac{\text{weight of biodiesel produced(g)}}{\text{weight of raw oil used(g)}} \times 100\% \quad (2)$$



**Figure 2:** Transesterification oils into biodiesel

## 2.2 Fuels

**Table I** shows the samples of fuels used for this study

S/NO	Fuels	Abbreviation
1	Yellow Oleander Biodiesel	Y. O
2	Residual cooking oil Biodiesel	R. C. O
3	Diesel	D
4	50% Yellow Oleander blend with 50% Diesel	50%Y.O/50%D
5	50% Residual cooking oil blend with 50% Diesel	50%R.C.O/50%D

## 2.3 Engine performance test procedure

The engine performance procedure was carried out on diesel, Yellow Oleander, Residual cooking oil and their blends. A measuring cylinder was used to measure 500ml of the fuel sample and poured into the engine fuel tank. The switch was turned on while the choke was closed by pushing the lever down and the throttle was opened slightly, the starting handle on the left of the engine and was rotated until the engine fires. The throttle was adjusted to bring the speed up slightly while the engine run idle for about 10minutes in order to warm up the engine.

The first test condition was set by gradually opening the throttle and increasing the flow of water to the dynamometer until the engine is running on the load of 9Nm and throttling at about 2160rpm until the engine was stabilized then the readings of the engine speed, torque, exhaust temperature and air flow rate were taken. The fuel flow rates were measured by turning off the fuel tap so the fuel is consumed only from the pipette, then a stop watch to measure the time

taken by the engine to consume 8ml of fuel from the pipette. This procedure was carried for varying speeds (2160, 1860 and 1560rpm) while keeping the load constant and constant speed while varying the loads (4, 7.5 and 10.6Nm).

### 3. Results and discussion

#### 3.1 physicochemical properties of the fuels

Table 2 below shows the physico-chemical properties of the fuels. It shows that RCOB has the highest density, highest kinematic viscosity at 30°C and highest calorific value while YOB has the highest cetane number.

**Table 2:** Physicochemical properties of the fuels used

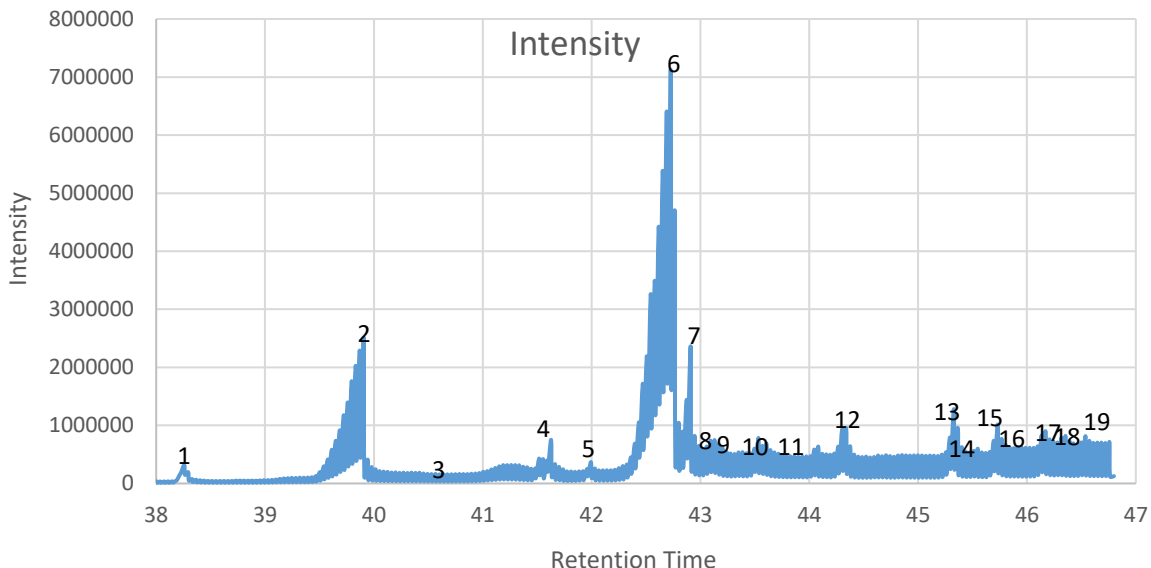
S/N	Properties	Yellow Oleander Biodiesel	Soybeans Residual cooking oil Biodiesel	Diesel	Biodiesel Standard
1	Density (g/cm <sup>3</sup> ) (@ 30°C)	0.81	0.90	0.88	0.86 – 0.90
2	Kinematic Viscosity (mm <sup>2</sup> /sec) (@ 30°C)	7.72	9.46	6.09	1.9 – 6.0
3	Free Fatty Acid (mg/g)	0.15	0.20	---	---
4	Acid Value (mg KOH/g)	0.30	0.40	---	0.50 Max
5	Saponification value (mg/g)	197.75	201.28	---	370 Max
6	Iodine Value (gI <sub>2</sub> /100g)	9.39	10.22	---	---
7	Moisture Content (%)	2.14	1.17	----	0.06 Max
8	Biodiesel Yield (%)	87.30	82.80	---	---
9	Flash Point (°C)	87.00	96.00	88.00	93.00 Min
10	Peroxide Value (meq.O <sub>2</sub> / KgOil)	0.40	0.90	---	---
11	Fire point (°C)	92.70	105.20	67	---
12	Cloud Point (°C)	-2.00	1.00	2.00	---
13	Pour Point (°C)	-5.30	-5.80	-2.00	-3 to -12
14	Refractive Index	1.49	1.50	---	-15 to -16
15	Cetane Number	71.79	71.42	41.00	47.00 Min
16	Calorific value (MJ/Kg)	47.24	49.53	45.87	---

#### 3.2 GCMS Results of yellow oleander and residual cooking oil biodiesels

##### 3.2.1 GCIMS Result of Yellow Oleander Biodiesel

Figure 3 shows that yellow oleander contains about 86.24% biodiesel, with the highest peak number of 2, 6, and 7. These peaks corresponds to n-Hexadecanoic acid, cis-13-Octadecenoic acid and Octadecanoic acid methyl esters with total percentage covering areas of 76.98%, while the remaining total percentage covering areas of 23.01% includes Hexadecanoic acid, methyl ester. The presence of methyl ester profile is one of the key indicators that determines the

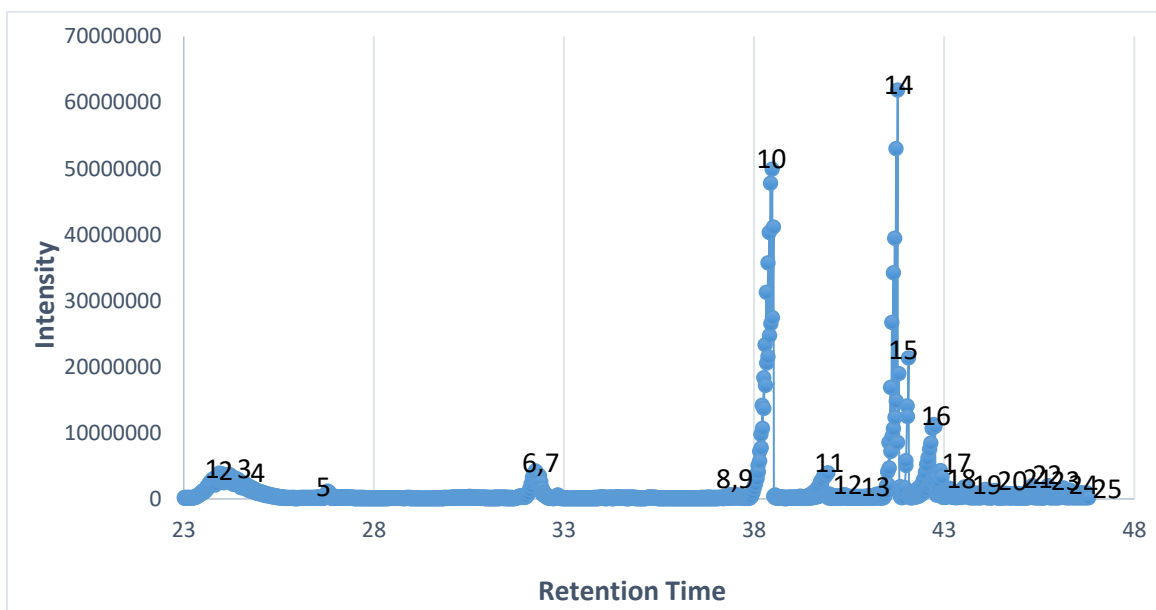
sustainability of biodiesel feedstock (Sokoto et al., 2011). It can, therefore, be concluded that yellow oleander biodiesel has the required quality to be used in compression ignition engines.



**Figure 3:** GCMS result of yellow oleander biodiesel

### 3.2.2 The GC/MS Result of Residual Cooking Oil Biodiesel

Figure 4 shows that GCMS analysis of soyabeans residual cooking oil biodiesel reveals that fatty acid methyl ester (FAME) components are the highest dominant with Hexadecanoic acid-methyl ester and cis-13-Octadecenoic acid-methyl ester representing peak number 10 and 14 respectively with percentage area of 61.22% in aggregate. This is an indication that Residual Cooking Oil biodiesel contains high percentage of unsaturated carbonyl compound which may account to low cetane value of the biodiesel fuel (Chukwueziel et al., 2007). Hence, this result is in line with that of Sahar et al (2018) and can be concluded that residual cooking oil biodiesel has the required quality to be use in compression ignition.



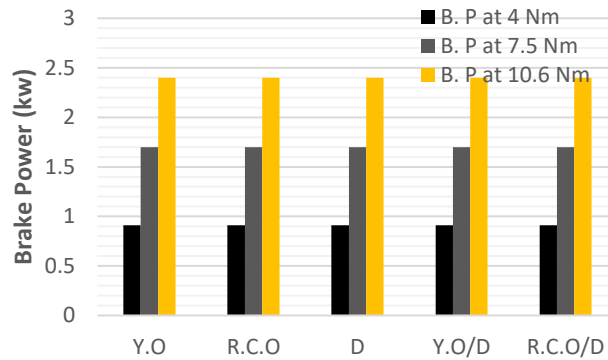
**Figure 4:** GCMS result of residual cooking oil biodiesel

### 3.3 Engine Test Results

This section discusses results of the engine performance and emission characteristics of the fuels.

#### 3.3.1 Brake Power (BP) at constant speed and variable torque

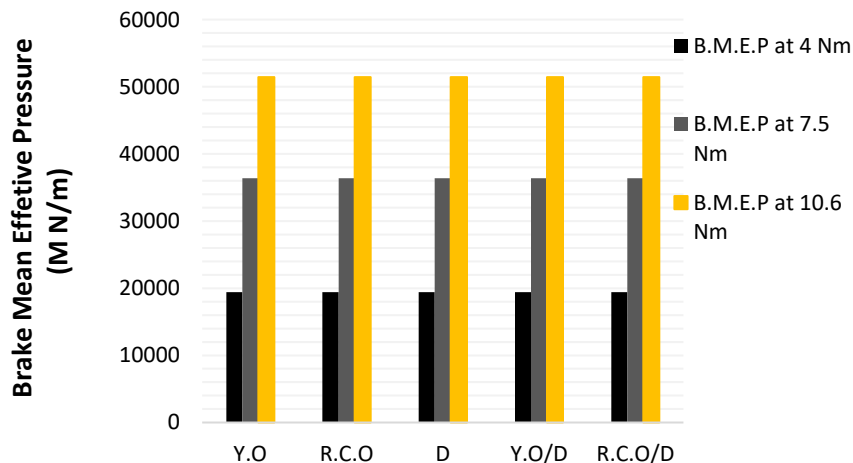
Figure 5 reveals that B.P increases with increase in torque for all fuels. It shows that RCOB has the lowest B.P of 0.91kw at the engine torque of 4 Nm, followed by 1.70kw at 7.5Nm and the highest brake power of 2.40kw at 10.6Nm. The B.P increases by about 62% from engine torque of 4Nm to 10.6Nm. However, regardless of the fuel tested, B.P is the same for all the fuels at a fixed torque, this can be explained that the same engine parameters were used to analyze the fuels, therefore it is not fuel dependent but engine dependent.



**Figure 5:** Variation of brake power with torque

#### 3.3.2 Brake mean effective pressure (B.M.E.P) at constant speed and variable torque

Figure 6 shows that the BMEP of the fuel samples increased with increase in engine torque from 4Nm to 10.6Nm. It reveals that Y.O.B has the lowest BMEP of 19401.02 MN/m<sup>2</sup> at engine torque of 4Nm, further increase to 36376.87 MN/m<sup>2</sup> at 7.5Nm and have the highest BMEP of 51412.57 MN/m<sup>2</sup> at the highest torque of 10.6Nm. However, it can further be deduced that BMEP increased by about 62% from the lowest torque of 4Nm to the highest torque of 10.6Nm for the fuels, which was found to be the same for all the fuels at each particular engine torque.



**Figure 6:** Variation of brake mean effective pressure with torque

### 3.3.3 Specific fuel consumption (S.F.C) at constant speed and variable torque

Figure 7 shows that S.F.C decreased with increase in the engine torque from 4Nm to 10Nm irrespective of the fuel analyzed. The S.F.C of diesel was 0.52kg/kwh at the lowest torque of 4Nm, and it drastically decreased to 0.28kg/kwh when the torque was increased to 7.5Nm and then to 0.17kg/kwh at the highest engine torque of 10.6Nm. However, it was observed that the S.F.C decreased by 46% as the torque increases from 4Nm to 10.6Nm. This result implied that at the highest torque the S.F.C is low for all the fuel sample tested and increases as the engine torque was decreased, the S.F.C seemed not to depend only the engine but also on the fuel combusted.

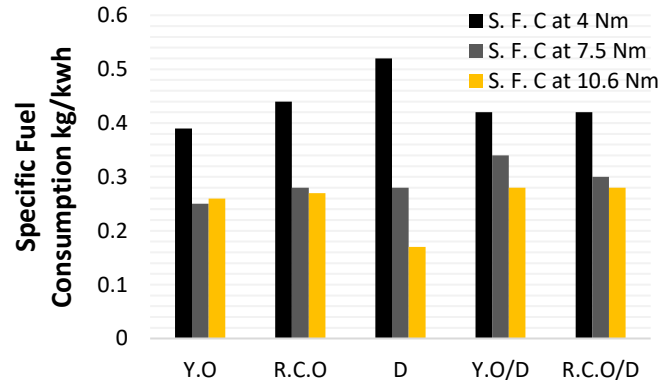


Figure 7: Variation of specific fuel consumption with torque

### 3.3.4 Exhaust Temperature at constant speed and variable torque

Figure 8 shows that the exhaust temperature for all the fuel molecules increases with increase in the engine speed except for diesel. Considering yellow oleander from the graph below, it has its lowest temperature of 122°C at the lowest engine torque of 4Nm, and then increased to 152°C at 7.5Nm, and has the highest exhaust temperature of 188°C at the highest torque of 10.6Nm. However, yellow oleander has 35% increase in the exhaust temperature from the lowest engine torque of 4Nm to the highest torque of 10.6Nm, this increase in exhaust temperatures can be traced to the fact that biodiesel is more oxygenated than diesel, there is more oxygen available for combustion.

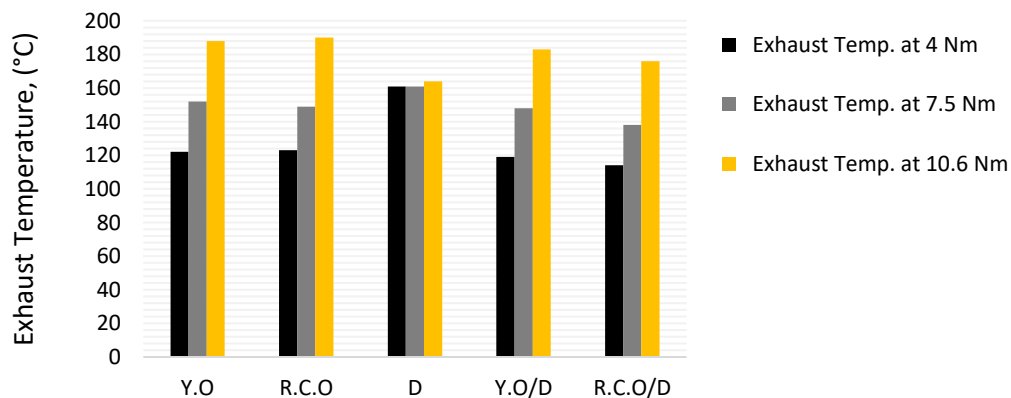


Figure 8: Variation of Exhaust temperature with torque

### 3.3.5 Air fuel ratio (A. F. R) at constant speed and variable torque

Figure 9 shows that the A.F.R for yellow oleander, residual cooking oil and diesel decreased with increase in the engine torque while that of their blends behaves otherwise which reason cannot be obviously explained. It shows that yellow oleander has a flow rate of  $0.62\text{m}^3/\text{s}$  at lowest torque of  $4\text{Nm}$ , it then decreased to about  $0.53\text{m}^3/\text{s}$  at  $7.5\text{Nm}$  and having the least A.F.R of  $0.43\text{m}^3/\text{s}$  at the highest torque of  $10.6\text{Nm}$ . It can further be seen that the A.F.R for yellow oleander decreased by about 31% from the lowest torque of  $4\text{Nm}$  to the highest engine torque of  $10.6\text{Nm}$ .

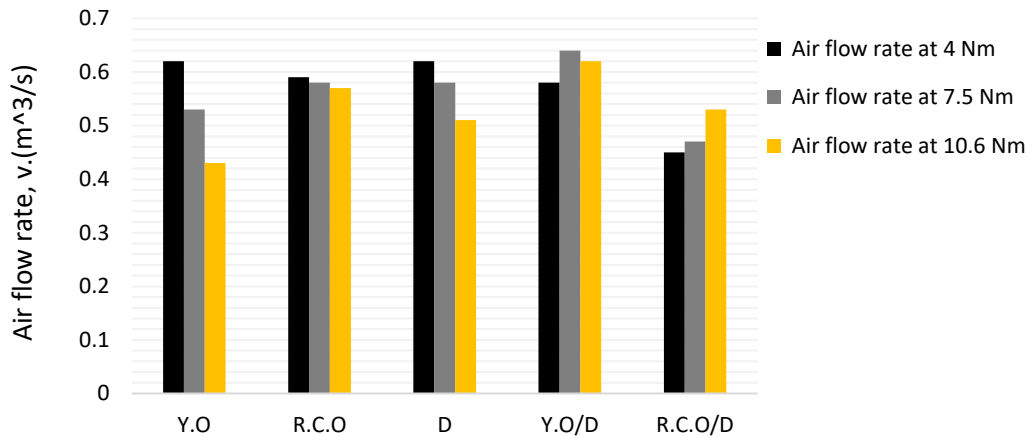


Figure 9: Variation of Air flow rate with torque

### 3.4 Emission Characteristics

#### 3.4.1 CO<sub>2</sub> at constant speed and variable Torque

Figure 10 reveals that CO<sub>2</sub> emission of all the fuels increased from the lowest torque of  $4\text{Nm}$  to the highest engine torque of  $10.6\text{Nm}$ . It can be observed that residual cooking oil has the highest CO<sub>2</sub> emission reduction of about 47% at the lowest engine torque of  $4\text{Nm}$ , then followed by 43% CO<sub>2</sub> emission reduction and has the lowest CO<sub>2</sub> emission reduction of 33%. However, it can be observed that CO<sub>2</sub> emission for the diesel is higher at each fixed torque than the two biodiesels and their blends which deduced that the biodiesel are good in terms of CO<sub>2</sub> emission reduction.

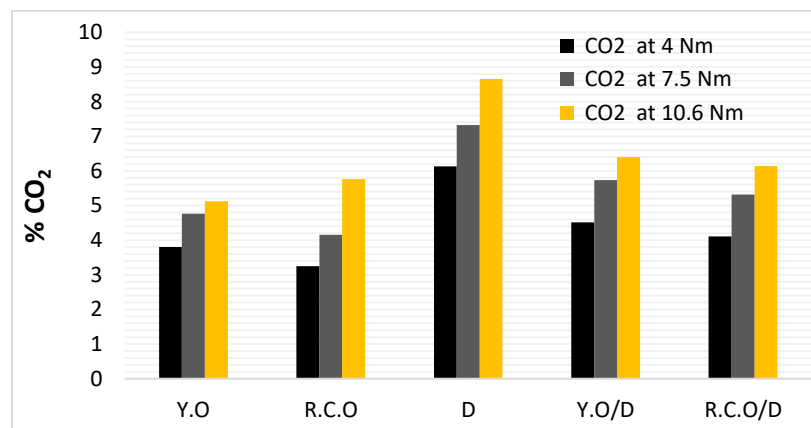


Figure 10: Variation of %CO<sub>2</sub> emission with torque



### 3.4.2 NO<sub>x</sub> emission at constant speed and variable Torque

Figure 11 shows that the NO<sub>x</sub> emission for all the fuels tested increased with increase in the engine torque from the lowest to the highest. Yellow oleander emits it lowest NO<sub>x</sub> of 235ppm at the lowest torque of 4Nm, the emission increases to 374ppm at engine torque of 7.5Nm and has it highest NO<sub>x</sub> of 512ppm at the highest torque of 10.6Nm. Therefore, the NO<sub>x</sub> emission of yellow oleander increased by about 54% from the lowest torque of 4Nm to the highest torque of 10.6Nm. However, it can be seen that all the biodiesels and their blends emit higher NO<sub>x</sub> than diesel at the different engine torque which may be due to the present of high amount oxygen in biodiesel and hence, enhance formation of NO<sub>x</sub> gases.

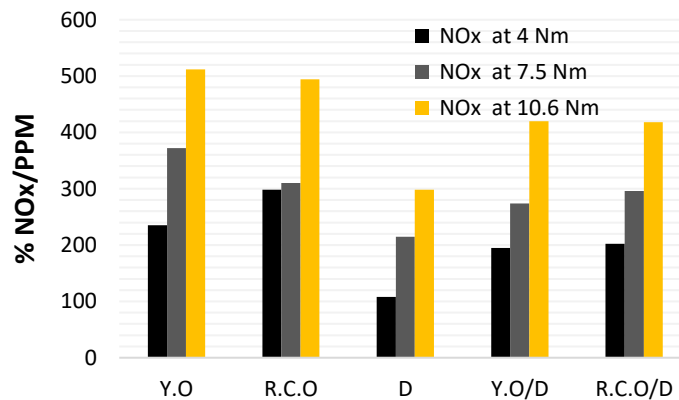


Figure 11: Variation of % NO<sub>x</sub> emission with torque

### 3.4.3 CO at constant speed and variable Torque

Figure 12 shows that CO emission increased with increase in the torque for the fuels with diesel having the highest CO emission at each particular torque tested. It can be observed that yellow oleander has the highest CO emission reduction of about 67% at the torque of 4Nm as compared to diesel at the same torque, followed by 44% CO reduction at 7.5Nm and then reduces to 50% CO reduction at the highest torque of 10.6Nm. However, the diesel emitted higher amount of CO emission than the biodiesels and their blend.

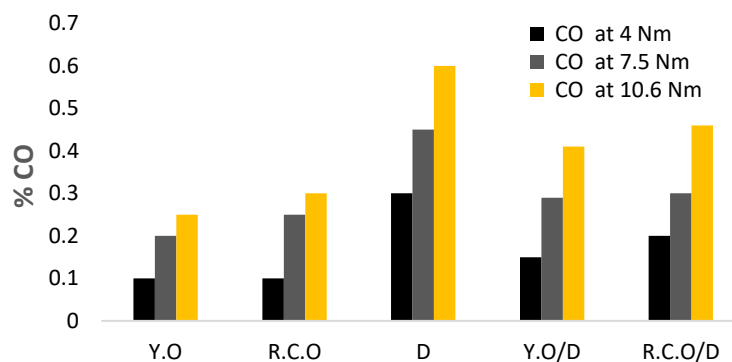
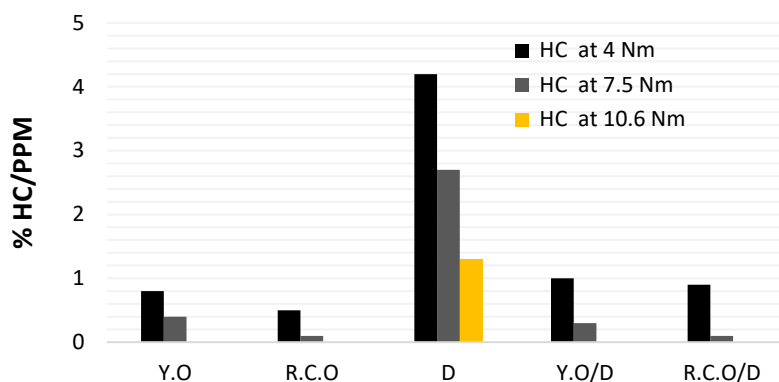


Figure 12: Variation of %CO emission with torque

### 3.4.4 HC at constant speed and variable Torque

Figure 13 shows that the HC emission decreased with the increase in the engine torque for the fuels tested, at the highest torque of 10.6Nm, it can be seen that the biodiesel and their blends have no HC emission except for diesel. Taking diesel for example, it emits the highest unburnt HC of 4.2%HC/ppm at the lowest torque of 4Nm and then followed by 2.7%HC/ppm at 7.5Nm

and having the lowest emission of 1.3%HC/ppm at highest torque of 10.6Nm. however, about 69% reduction in unburnt HC emission is observed for diesel from the lowest torque of 4Nm to the highest torque 10.6Nm.



**Figure 13:** Variation of % unburnt HC emission with torque

### 3.5 The comparison between the biodiesels and diesel in term of emission reduction

Table 3 shows the variation of exhaust gases emission reduction and increase for all the fuel molecules investigated as compared to diesel. With the negative sign signifying the percentage of emission reduction while the positive sign means increase in the emission with reference to diesel.

**Table 3** Represent the comparison between biodiesel and diesel at constant engine speed and variable torque.

Fuels/Torque(Nm)	CO			CO <sub>2</sub>			NO <sub>x</sub>			HC		
	@ 4	@ 7.5	@10.6	@ 4	@ 7.5	@10.6	@ 4	@7.5	@10.6	@ 4	@ 7.5	@10.6
Y.O	-57%	-56%	-58%	-38%	-35%	-41%	+54%	+42%	+42%	-81%	-85%	-100%
R.C.O	-57%	-44%	-50%	-47%	-43%	-33%	+64%	+31%	+40%	-88%	-96%	-100%
50%Y.O/50%D	-50%	-36%	-32%	-26%	-22%	-26%	+45%	+22%	+29%	-76%	-89%	-100%
50%R.C.O/50%D	-33%	-33%	-23%	-32%	-27%	-29%	+47%	+27%	+29%	-79%	-96%	-100%

### 4. Conclusion

From the result of the experiment, exhaust temperature increased with increase in torque for all the fuels samples tested, likewise the air consumption rate at each specific torques.

In term of engine emission characteristics, the Carbon II oxides (CO) emissions decrease with increase in torque, while Oxides of Nitrogen (NO<sub>x</sub>) for yellow oleander, residual cooking oil and their blends were higher than that of the diesel at each fixed torque tested. However, Carbon IV Oxides (CO<sub>2</sub>) emissions increased with increase in torque. The diesel emitted higher amount CO<sub>2</sub> at each torque than the biodiesels and their blends.

Therefore, immense emissions are being produced during the operation of heavy and light duty diesel engines. Biodiesel from yellow oleander and residual cooking can be used as part of substitutes for compression ignition engines to reduce the effects of greenhouse gases emissions caused by fossil diesel fuel combustion and also provide employment opportunity in Nigeria.

## References

- Alamu, OJ., Akintola, TA., Enweremadu, CC. and Adeleke, AE. 2008. Characterization of palm-kernel oil biodiesel produced through NaOH-catalysed transesterification process. Scientific Research and Essay, 3(7): 308-311.
- Akintayo, ET. 2004. Characteristics and composition of Parkia biglobossa and Jatropha curcas oils and cakes. Bioresource Technology, 92: 307 – 310.
- Atadashi, I., Musa, AM., Abdul, R., Abdul, A., Nik, S. and Nik, M. 2012. Production of biodiesel using high free fatty acid feedstocks. Renewable and Sustainable Energy Reviews, 16(5):3275-3285, DOI:[10.1016/j.rser.2012.02.063](https://doi.org/10.1016/j.rser.2012.02.063)
- Azeem, MW., Hanif, MA., Al-Sabahi, JN., Khan, AA., Naz, S. and Ijaz, A. 2016. Production of biodiesel from low priced, renewable and abundant date seed oil. Renewable Energy 86: 124-132.
- Batidzirai, B., Faaij, PC., André, S. and Edward, LC. 2006. Biomass and bioenergy supply from Mozambique, Energy for Sustainable Development, 10(1): 54-81.
- Broek, VR. 2000. Sustainability of Biomass Electricity Systems. An Assessment of Costs, Macroeconomic and Environmental Impacts in Nicaragua, Ireland and the Netherlands, Eburon Delft.
- Chukwuezie, OC., Nwakuba, NR., Asoegwu, SN. and Nwaigwe, KN. 2017. Cetane number effect on Engine performance and Gas emissions: A review. American Journal of Engineering Research (AJER), 6(1): 56-67, [www.ajer.org](http://www.ajer.org).
- Dutta, AC. 1964. Botany for Degree Students, 5th edn., Oxford: Oxford University Press.
- Gupta, PK., Kumar, S., Panesar, BS. and Thapar, VK. 2007. Parametric Studies on Bio-diesel prepared from Rice Bran Oil. Agricultural Engineering International: the CIGR Ejournal. Manuscript EE 06 007. Vol. IX.
- Hellier, P., Nicos, L. and Talal, Y. 2015. The influence of straight vegetable oil fatty acid composition on compression ignition combustion and emission. Fuels, 143:131-143.
- Ibiyemi, SA., Fadipe, VO., Akinremi, OO. and Bako, SS. 2002. Variation in oil composition of Thevetia peruviana juss fruits seeds. Journal of Applied Science and Environmental Management, 6(2): 61-65.
- Ibrahim, H., Ezeanyanso, C., Hayatudeen, A., Nwakuba, DCU., Olabimtan, O., Aminu, A. and Ibrahim, AM. 2014. Comparison of palm Oil and Jatropha curcas seed Oil for Biodiesel Production in Nigeria Using Bulk CaO Catalyst. International Journal of Emerging Technologies and Engineering (IJETE), 1(1): 28-32., [www.ijete.org](http://www.ijete.org)
- Jamil, F., Ala'a, HA., Lamy, A., Mohab, AA., Paul, H. and Umer, R. 2016. Optimization of oil extraction from waste "Date pits" for biodiesel Production. Energy Conversion and Management, 117: 264–272.
- Jaynes, D. 2010. Global Warming: Myths and Realities. Social Sciences, SOC 461-11

Kaisan, MU., Anafi, FO., Nuzzkowski, J., Kulla, DM. and Umaru, S. 2017. Exhaust emissions of biodiesel binary and multi-blends from cotton seed, Jathropha and Neem oil from stationary multi cylinder CI engine. *Transportation Research part D. Transport and Environment*, 53: 403-414.

DOI:10.1016/j.trd.2017.04.040. Available on [www.elsevier.com/locate/trd](http://www.elsevier.com/locate/trd).

Mofijur, M., Masjuki, HH., Kalam, MA., Atabani, EA., Riwanal, F. and Mobarak, HM. 2014. Comparative evaluation of performance and emission characteristics of MoringaOleifera and palm oilbased biodiesel in a diesel engine. *Journal of Industrial Crops and Product*, 53:78-84.

Niyi, A. 2011. Generator Diesel Exhaust: A Major Hazard to Health and the Environment in Nigeria. *American Journal of Respiratory and Critical Care Medicine*, 183(10): 1437.

Rubi, R., Sandra, LM. and Reyna N. 2011. Biodiesel Production by Using Heterogeneous Catalysts, *Alternative Fuel*, Dr. Maximino Manzanera (Ed.), Biotechnology, InTechOpen Publishers London, Available from: <http://www.intechopen.com/books/alternative-fuel/biodiesel-production-by-using-heterogeneous-catalysts>

Tuba, HD. 2016. The testing of the effects of cooking conditions on the quality of biodiesel produced from waste cooking oils. *Renewable Energy*, 94: 466-473., <http://dx.doi.org/10.1016/j.renene.2016.03.088>

Sokoto, MA., Hassan, LG., Dangoggo, SM., Ahmad, HG. and Uba, A. 2011. Biodiesel fuel. *Nigeria Journal of Basic and Applied Science*, 19(1): 81-86.

Tukur, Y. 2016. Assessment and modeling of emission impact of biodiesel produced from calabash, silk cotton and palm kernel seeds and their performance evaluation on internal combustion engines. [American Chemical Science Journal](http://www.acs.org) 14(4):1-8. DOI:[10.9734/ACSJ/2016/25472](https://doi.org/10.9734/ACSJ/2016/25472)