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Effect of diesel-biodiesel and diesel-biodiesel-ethanol blends on physicochemical properties and gases emission of *Baobab* biodiesel

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Abstract
Biodiesel from Baobab seed oil was produce using transesterification reaction. The blends ratios were as follow; B20 (20% biodiesel, 80% diesel) B20E20 (20%biodiesel, 20%Ethanol, 60%diesel) and B20E30 (20%biodiesel, 30%Ethanol, 50%diesel). Biodiesel, B20, B20E20, and B20E30 had the following physicochemical properties: Density at 15°C g/cm^3 (0.8866, 0.8519, 0.8403, and 0.8864 g/cm^3 respectively), Kinematic viscosity in 40°C (5.8, 3.6, 3.4, and 2.7 cSt respectively), total Acid Number mgKOH/g (0.20, 0.16, 0.14, and 0.13), Calorific value (44.051, 44.354, 44.456, and 44.5 MJ kg -1 respectively), Cloud point (+7, +12, +8, and +8 °C), Pour point (+6, -6, -8,and-12°C), flash point was 80 for biodiesel and 67 for B20 Water Content wt% (0.1, 0.05, 0.056, and 0.048) Copper Strip Corrosion 3 Hours at 100ºC (1b, 1a, 1a, and1a). The experimental results of emissions in diesel engine at different speeds for standard diesel and blends showed that the carbon dioxide and NO_X emissions decrease when blends used over diesel. B20 (20% biodiesel and 80% diesel) showed lowest emissions levels.

Keywords: Physicochemical, biodiesel, ethanol blends, gases emission, Baobab, (*Adansonia digitata* L.), diesel engine, Ester content

1. Introduction

Biodiesel is advised for use as an alternative fuel for conventional petroleum-based diesel chiefly because it is a renewable, domestic resource with an environmentally friendly emission profile and is readily biodegradable [1]. The amount of greenhouse gas emissions, generating energy from renewable resources is being possessed a high priority gradually to decrease both over-reliance on imported fossil fuels [2]. In accordance with the US Standard Specification for Biodiesel (ASTM 6751), biodiesel is defined as a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats [3]. It has similar physicochemical properties of conventional fossil fuel and can consequently, entirely or partially substitute fossil diesel fuel in compression ignition engines [4]. Biodiesel satisfy the ASTM and EN limits, it cannot be used alone in diesel engine due to its high kinematic viscosity and density and also lower oxidation stability and heating value [5]. To improve those properties, it is blended with diesel. Physicochemical properties such as kinematic viscosity, calorific value, density, flash point, cloud point, pour point, CFPP, effected with the varying blended percentage, Bio- diesel, B20, B20E20 and B20E30 [6]. Viscosity is an important property of biodiesel since it affects the operation of fuel injection equipment (at low temperatures affects the fluidity of biodiesel) [7]. Higher viscosity leads to a higher drag in the injection pump and thus causes higher pressures and injection volumes, especially at low engine operating temperatures [8]. Density and therefore specific gravity is another important parameter of biodiesel quality. Fuel injection equipment operates on a volume metering system, hence a higher density for biodiesel results in the delivery of a slightly greater mass of fuel [7]. The cloud point is the lowest temperature at which smallest observable cluster of wax crystal first appears [9]. The Pour point is the lowest temperature at which the wax becomes semisolid and loses its flow characteristics. In general, biodiesel has higher CP and PP than diesel. The CP and PP of biodiesel feedstock largely depends on fatty acid composition [10]. Flash point is a measure of the flammability of fuels and thus, an important parameter for assessing hazards during fuel transport and storage. Biodiesel used as blends in different portions to petroleum diesel showed that on combustion of biodiesel – petroleum diesel blends, the level of carbon monoxide (CO), carbon di-oxide (CO_2) were reduced significantly; whereas the amount of oxides of nitrogen (NO_X) was increased, since biodiesel is oxygenated, engines have more complete combustion than with ordinary diesel [11]. Mono-nitrogen oxides NO and NO_2 nitric oxide and nitrogen dioxide are termed as NOx. They are produced from the reaction of nitrogen and oxygen gases in the air during combustion at high temperatures [12]. The oxides of nitrogen (NO_x) are precarious pollutant emissions, which are produced, when the fuel is burnt at high temperature causing dissociation of N_2, which ultimately leads to the formation of nitric acid. The NO_x is also responsible for weakening the ozone layer [13]. NO_x emission is from biodiesel increases or decreases depending on the engine family and testing procedures [13].

2. Material and Methods

2.1 Biodiesel production

500 ml of acid treated oil were placed into a 1 L beaker and heated up to 60°C, 100 ml of fresh methanolic Sodium Hydroxide were added under stirring at 3000 rpm for two hours. The mixture was transferred to a separating funnel and

kept for 24 hours. Then the lower, glycerol layer was drained and the upper biodiesel layer was washed, three times, with warm distilled water to remove soap, methanol and remaining glycerol [14].

2.2 Identification of *Boabab* Biodiesel

Ester content of *Boabab* biodiesel was determined using GC-2010 gas chromatograph (SHIMADZU). Capillary column DB-1 (30m×0.25mm×0.25mm). The detector temperature was programmed at 300ºC with flow rate of 30.0 ml/min. The injection mode was split, the temperature was set at 250ºC, nitrogen and air were used as the carrier gas. The identification of the peaks Characteristic and Composition of Baobab seed Oil achieved by retention times by means of comparing them with authentic standards analyzed under the same conditions.

2.3 Blending of the samples

The B20 was produced with (%, v/v) 20 ml of bio diesel with 80 ml diesel, the two ethanol-diesel blends were produced with (%, v/v) 20 ml and 20 ml of bio diesel with 20 ml and 30 ml of ethanol the volumes were completed with diesel, and the blends were labeled as B20E20 and B20E30 respectively.

2.4 Physical and chemical properties of *Boabab* Biodiesel and its blends

2.4.1 Density at 15ºC (g/cm^3)

A small volume (approximately 0.7 ml) of liquid sample was introduced into an oscillating sample tube and the changed in oscillating frequency caused by the change in the mass of the tube was used in conjunction with calibration data to determine the density of the sample [15].

2.4.2 Specific gravity

The sample was brought to a specified temperature and a test portion was transferred to a hydrometer cylinder that had been brought to approximately the same temperature. The appropriate hydrometer, also at a similar temperature, was lowered into the test portion and allowed to settle. After temperature equilibrium had been reached, the hydrometer scale was recorded, and the temperature of the test portion was taken [16].

2.4.3 Kinematic viscosity in 40ºC (cSt)

The time was measured for a fixed volume of liquid to flow under gravity through the capillary of a calibrated viscometer under a reproducible driving head and at a closely controlled and known temperature. The kinematic viscosity was the product of the measured flow time and the calibration constant of the viscometer [17].

2.4.4 Calorific value (MJ kg^{-1})

Adiabatic bomb calorimeter was used in the experiment. The effective heat capacity of the calorimeter was determined using benzoic acid of a certified calorific value of 26.4698 MJ/kg under standard conditions. About 1 ml of distilled water was pipetted into the bomb. An accurately weighed sample of the order of 0.5 g was introduced into the oil cup and placed in the bomb. A length of fine cotton thread was suspended in the sample from a nickel-chromium wire in order to act as a source of ignition. The bomb was assembled and charged with oxygen at 35 atmospheres. The initial temperature of the calorimeter was adjusted to about 275°K below ambient temperature to minimize heat losses. After about five minutes of natural heat transfer to the jacket water, the firing circuit was closed, and the temperature of the jacket water recorded until it was found to fall for a period of about five minutes. The temperature rise was noted and the net calorific value was calculated using the equation below. The experiment was carried out in triplicate allowing a difference of about 0.28 MJ/Kg between the values obtained [18].

Calculation: Calorific value (cal/g) = (water equivalent (g) + water quantity of inner cylinder) × raised temperature (°C) – calory correction /quantity of sample (g)

2.4.5 Cloud point (ºC)

The sample was brought to be tested to a temperature at least 14°C above the expected cloud point. Any moisture presented was removed by a method such as filtration through dry lintless filter paper until the oil was perfectly clear, but made such filtration at a temperature of at least 14°C above the approximate cloud point. The sample was poured into the test jar to the level mark. The test jar was closed tightly by the cork carrying the test thermometer [19].

2.4.6 Pour point (ºC)

The sample was cooled after preliminary heating at a specified rate and examined at intervals of 3°C for flow characteristics. The lowest temperature at which movement of the specimen was observed and recorded as the pour point [20].

2.4.7 Flash point (°C)

The samples were placed in closed-cup tester to measures the flash point at the lowest temperature at which the application of an ignition source causes the vapors of a sample to ignite**.** Also acid number, water content, Copper Strip Corrosion and all physicochemical properties for blends were determined according to ASTM D7467 "Standard Specification for Diesel Fuel Oil, Biodiesel Blend (B6 to B20)"

2.5 Engine test for the gases emission

Table (1) showed the diesel engine specification. The gas analyzer were connected to Exhaust. The gases concentrations were taken in three different speeds1000, 1500, and 2000 rpm.

Table 1: Diesel engine specification

Item	Value
Engine model	2L–T Toyota 1985
Engine type	4-cylinder diesel engine
Displacement	2.4 L
Cylinder bore and strok	92mm
Cooling system	Radiator cooling
Compression ratio	20:1

3. Results and Discussion

3.1 Identification of *baobab* Biodiesel and Ester content

Table 2 shows the fatty acid methyl esters which found in the

Baobab biodiesel and their yield. The total ester content in the biodiesel was 98.4% of the total components of produced *Baobab* biodiesel which indicate successful biodiesel production and prove that the triglycerides were converted to methyl ester. The methyl esters with higher percentage were in the order Palmitoleic Acid methyl ester, Myristic Acid methyl ester and Lauric Acid methyl ester with percentage of 46.08 %, 19.48 % and 12.24 % respectively. Saturated FAME was found 50.871% while unsaturated FAME was found 74.537%.

Table 2: Ester content of *Baobab* Biodiesel

No.	Name	Formula	Area %
1	Caproic acid M.E	$C_6H_{12}O_2$	0.1122
2	Capric acid M.E	$C_{10}H_{20}O_2$	0.3740
3	Lauric acid M.E	$C_{12}H_{24}O_2$	12.2408
4	Myristic acid M.E	$C_{14}H_{28}O_2$	19.4814
5	Cis- 10-Pentadecenoic acid M.E	$C_{15}H_{30}O_2$	7.6434
6	Palmitoleic acid M.E	$C_{16}H_{30}O_2$	46.0843
7	Palmitic acid M.E	$C_{16}H_{32}O_2$	2.3675
8	Cis- 10-Heptadecenoic acid M.E	$C_{17}H_{34}O_2$	5.0237
9	Heptadecenoic acid M.E	$C_{17}H_{34}O_2$	2.0205
10	Linolelaidic acid M.E – alpha-Linolenic acid M.E	$C_{18}H_{32}O_2$	0.6034
11	Elaidic acid M.E	$C_{18}H_{34}O_2$	0.1335
12	Stearic acid M.E	$C_{18}H_{36}O_2$	0.7314
13	Arachidic acid M.E	$C_{20}H_{40}O_2$	0.9883
14	Cis-8,11,14-Eicostrienoic acid M.E	$C_{20}H_{32}O_2$	0.4570
15	Cis- 11- Eicosenoic acid M.E	$C_{20}H_{38}O_2$	0.1470

3.2 Physicochemical analysis of biodiesel and blends.

The data presented in Table (3) shows the physicochemical characterization of *Adansonia digitata* biodiesel and blends. The density of Biodiesel, B20, B20E20 and B20E30 was obtained at 0.8866, 0.8519, 0.8403 and 0.8864 g/cm^3 respectively which showed similarity to both studies reported by Buhari *et al*. [21] and Danbature *et al*. [22] which were 0.86 and 0.8553g/cm^3 respectively for the same plant. The Kinematic viscosity of Biodiesel, B20, B20E20 and B20E30 was obtained at 5.8, 3.6, 3.4 and 2.7 cSt respectively. The Kinematic viscosity value of Biodiesel was higher than that determined by Buhari *et al*. [21] and Danbature *et al*. [22] which were 0.859 ± 0.0349 and 3.144 cSt respectively. The calorific value of Biodiesel, B20, B20E20 and B20E30 was obtained at 44.051, 44.354, 44.456 and 44.5 MJ kg^{-1} respectively. The calorific value was similar to that reported by Danbature *et al.* [22] which was 44.063 MJ kg^{-1} for the same plant. Compared to diesel fuel, lower calorific value and higher viscosity which influenced the combustion characteristics. Fuels with high kinematic viscosity tend to form larger droplets during injection which can consequently lead to poor combustion. Therefore, the uneven combustion characteristics of the produced biodiesel fuel reduced the engine [23]. The cloud point of Biodiesel, B20, B20E20 and B20E30 was obtained at 7, 12, 8 and 8°C respectively. The cloud point value was lower to that reported by Buhari *et al*. [21] who was reported that pour point was 10°C for the same plant and higher to that obtained by Danbature *et al*. [22] which was 6°C. The pour point of Biodiesel, B20, B20E20 and B20E30 was obtained at 6, -6, -8 and -12°C respectively. The pour point value was higher comparable to that determined by Danbature *et al*. [22] which was -1.5°C, but it lower than that obtained by Buhari *et al*. [21] which was 10°C for the same plant. Fuel blends have the same pour point compared to biodiesel-diesel fuel blends. But biodiesel normally must be has a pour point higher than conventional diesel.The flash point of Biodiesel and B20 was obtained 80, 76°C respectively which was lower comparable to that determined by Danbature *et al*. [22] and Buhari *et al*. [21] which was 160, 170°C respectively.

Table 3: Physico-chemical properties of Baobab Biodiesel and blends

parameters	Biodiesel	B20	B20E20	B20E30	ASTM D 7467
Density at 15°C (g/cm^3)	0.8866	0.8519	0.8403	0.8364	-
Kinematic viscosity in 40°C (cSt)	5.8	3.6	3.4	2.7	1.9 – 4.1
Calorific value (MJ kg^{-1})	44.051	44.354	44.456	44.5	-
Total Acid Number (mgKOH/g)	0.20	0.16	0.14	0.13	Max. 0.3
Cloud point (°C)	+7	+12	+8	+8	-
Pour point (°C)	+6	-6	-8	-12	-
Flash point (°C)	80	76.0	-	-	Min. 52
Copper Strip Corrosion (3 Hours at 100°C)	1b	1a	1a	1a	Max.3
Water Content (wt %)	0.1	0.05	0.056	0.048	Max. 0.05

3.3 Gas emission of baobab biodiesel and blends

The data presented in Tables (4), (5), (6) and (7) showed the gases emission of baobab biodiesel and blends. The engine was set at a different speeds 1000, 1500 and 2000 rpm respectively. Due to the ethanol's low energy content, the power will decrease using the diesel–ethanol blended fuel. biodiesel used as blends in different portions to petroleum diesel showed that on combustion of biodiesel – petroleum diesel blends, the level of carbon monoxide (CO), carbon di-oxide (CO_2) were reduced significantly; whereas the amount of oxides of nitrogen (NO_X) was increased, since biodiesel is oxygenated, engines have more complete combustion than with ordinary diesel [14]. Mono-nitrogen oxides NO and NO_2 nitric oxide and nitrogen dioxide are termed as NOx. They are produced from the reaction of nitrogen and oxygen gases in the air during combustion at high temperatures [15]. NOx emission from biodiesel blends increases or decreases depending on the engine family and testing procedures [16]. From Figures (1) to (3), the gases emission values of CO2, NO and NOx showed that, the diesel had the highest concentration more than blends B20E20, B20E30 and B20 respectively.

Table 4: Gases emission of diesel

Speed (rpm)	CO_2 (%)	NO(ppm)	NO_x (ppm)
1000	2.0	56	58
1500	2.1	93	96

2000	2.3	122	128

Table 5: Gases emission of B20

Speed (rpm)	CO_2 (%)	NO (ppm)	NO_x (ppm)
1000	0.3	35	35
1500	1.0	45	47
2000	1.6	55	57

Table 6: Gases emission of B20E20

Speed (rpm)	CO_2 (%)	NO (ppm)	NO_x (ppm)
1000	1.2	75	79
1500	1.2	85	88
2000	2.0	119	124

Table 7: Gases emission of B20E30

Speed (rpm)	CO_2 (%)	NO (ppm)	NO_x (ppm)
1000	1.0	52	54
1500	1.2	70	78
2000	1.8	77	87

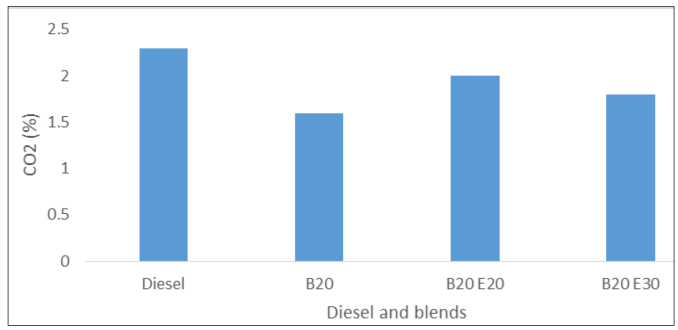

Fig 1: Diesel and Blends Vs CO_2 gas concentration

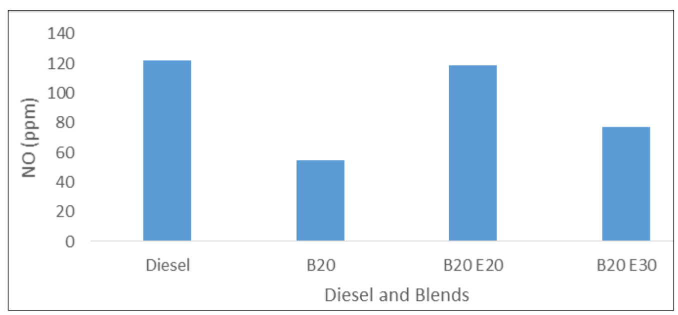

Fig 2: Diesel and Blends Vs NO gas concentration

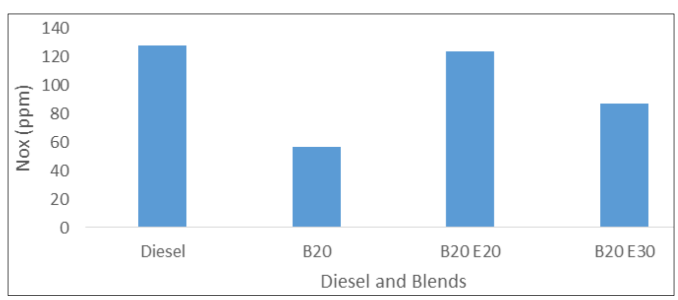

Fig 3: Diesel and Blends Vs NO_x gas concentration

4. Conclusion

In this study the ester content of Baobab biodiesel, physicochemical properties, and gases emission for Baobab biodiesel and blends B20, B20E20, and B20E30 were determined before its commercial application as an alternative fuel.

Blend (B20, B20E20 and B20E30) had met the requirements of ASTM D 7467.

CO_2 and NOx emissions of biodiesel blends (B20, B20E20 and B20E30) and petroleum diesel were studied carefully. Fuel consumption and NOx emissions increased and fuel efficiency decreased with increasing percentages of biodiesel beyond B20. B20 shows the lowest emissions level, however the petroleum diesel had the highest emissions.

The ratio of NOx and CO_2 is important for both improving fuel efficiency and reducing exhaust emissions for field operations in crop production.

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