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Research Article

Fuel Properties of Sandbox (*Hura crepitans* Linn.) Methyl Ester and its Blends

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ABSTRACT

Fuel properties of Sandbox Methyl Ester (SBME) blends were experimentally determined. Pure SBME designated B100 was blended with diesel at 5, 10, 15, 20, 25 and 50% volume designated B5, B10, B15, B20, B25 and B50 respectively. The fuel properties were determined according to American Society for Testing and Materials (ASTM) standards. Automotive Gas Oil (AGO) was used as a reference fuel. Fuel properties of the SBME were modified with the addition of diesel percentage in the blend from B100-B5: the density ranged from 891-865 kg m^{-3}. The specific gravity ranged from 0.87-0.82. The kinematic viscosity ranged from 5.8-4.0 mm^2 s^{-1}. The flash and fire point decreased from 160-90°C and 230-140°C, while the cloud and pour points ranged from 4.6-3.4°C and -5.8-(-9.2)°C respectively. The heating value ranged from 40.50-41.45 MJ kg^{-1}. The Cetane number for the SBME was 46.71. The saponification value ranged from 200-143 mgKOH g^{-1}. The acid value varied from 2.7-2.2 mgKOH g^{-1}, while the FFA content varied from 1.33-1.10 mg g^{-1}. The Iodine value was in the range of 108-94 gI2 $100g^{-1}$. The pH value varied from 6.80-5.60. The carbon content increased from 80.02-85.62 wt%, while the ash content increased from 0.01-0.16 g $100g^{-1}$. In comparison to the (AGO) and the ASTM standards, SBME was found to possessed good flow, ignition and combustion characteristics to power diesel engines.

RESEARCH ARTICLE

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INTRODUCTION

Petroleum fuel is still one of the major energy sources worldwide. However, the global concern of petroleum fuel depletion and potential extinction, in addition to environmental pollution from emissions from its combustion exhaust are facilitating researches into other energy sources to complement or totally substitute petroleum fuels (Reyes and Spulveda, 2006; Fangrui and Hanna, 1999; Haas, 2005; Kulkarni *et al.*, 2006). Biodiesel from organic lipids has become the available substitute to petroleum diesel. Biodiesel is a product of a displacement reaction known as transesterification between organic lipids such as vegetable oils, animal fats, waste oils and reprocessed lubricants and alcohol, mainly methanol or ethanol to form fatty esters such as methyl or ethyl ester (Goering *et al.*, 1982). As a result of pressure on other uses of vegetable oils, there is need for exploration and exploitation into discovering of more sources of non-edible vegetable oil to augment for the gap. One of such feedstocks is the sandbox seed oil. Sandbox is an underutilized plant, which is planted as a shade tree in villages and cities (Adewuyi *et al.*, 2012). Indigenous to tropical zones of North and South America, sandbox (*Hura crepitans* Linn.), is a tree of the (*Euphorbiaceae*) family recognizable by the shady, piercing backs and even brown exterior cover (Feldkamp, 2006). Sandbox seed has been found to contain oil and a number of important nutritional properties while the leaves can be used for medicinal purposes (Idowu *et al.*, 2012). There is no specific use of the oil from the sandbox seed at present as the seeds are discarded as waste (Adewuyi *et al.*, 2012). According to Basumatary (2013), sandbox seed contains about 53% oil. Biodiesel fuel properties are close and similar to that of common diesel, and therefore, can be used as fuel in its unadulterated state or a blend with diesel to drive ignition compression engines with minor or no modifications (Van Gerpen, 2005; Ma and Hanna, 1999). Biodiesel or its blend offers a variety of advantages over diesel fuel. As a biological source from plant and animal makes it is renewable, non-toxic, and its oil origin, density and viscosity give it better lubrication ability for engine parts (Demirbas, 2007). Biodiesel standards have been established in most countries in an effort to ensure that only high-quality biodiesel is available in the marketplace. The two most important fuel standards are the American Standard Testing and Measurement (ASTM) D6751 in the United States and EN 14214 (European Committee for Standardization, CEN) in the European Union. Several factors such as the type of catalyst used; either acid or base, the concentration of the catalyst, molar ratio of alcohol to vegetable oil, the reaction temperature, free fatty acid (FFA) content of the vegetable oil, and the purity level of the reactant especially the water content have great influence on the quantity and quality of methyl esters produced from vegetable oils (Zhang *et al.*, 2003; Ma and Hanna, 1999; Meher *et al.*, 2006; Van Gerpen, 2005). Various works have been reported on the fuel properties of so many vegetable oil methyl esters as shown in (Table 1). In characterizing fuel properties of sandbox seed methyl ester, Adewuyi *et al.* (2012) used two-step acid catalyzed pretreatment before the basic methanol transesterification. Also, the fuel properties of sandbox seed oil as reported by Adewuyi *et al.* (2012); Adepoju *et al.* (2013) and Igbum *et al.* (2012) were on the pure biodiesel and not comprehensive as some fuel properties were not determined. The present work produced methyl ester from sandbox seed by direct oil-methanol transesterification and evaluated essential fuel properties on the pure methyl ester and it blends with (AGO).

Table 1. Properties of vegetable oil methyl esters.

Vegetable oil methyl ester	Property D (kg m^{-3})	KV (mm^2 s^{-1})	FLP (°C)	FIP (°C)	CP (°C)	PP (°C)	CN	CV (MJ L^{-1})	AN (mgKOH g^{-1})
Sandbox	860-920	2.8-4.0		152	6	-15	45-50	40.30	0.21-2.34
Oil palm	835-880	5.7	183				62		
Linseed	870	4.2	161				48	37.5	
Jatropha	840-880	4.7	170	8			51	35-41	5.31
Sun flower	860	4.6	126	0	-2		49	38	
Soybean	680	3.2-4.5	118				45	42	
Sesame	700	5.3	170					44	
Rapeseed	882	4.2	157	10	-1		54	38	
Cottonseed	880	4.0	150	161				39	
Neem seed	820	3.8	245				47	40	
Rubber seed	850	5.8	130					33	

Adopted from Adewuyi *et al.* (2014); Adepoju *et al.* (2013); Sivaramakrishnan and Ravikumar (2012); Habibullah *et al.* (2015); Kumar and Sharma (2016); Cherng-Yuan Lin and Yi-Wei Lin (2012); Sathiyagnanam and Saravanan (2011). D: Density, KV: Kinematic Viscosity; FLP: Flash Point; FIP: Fire point; CP: Cloud point; PP: Pour point; CN: Cetane number; CV: Calorific value; AN: Acid number.

MATERIALS and METHODS

Preparation of Sandbox Seed Biodiesel

About 100 kg of mature sandbox fruits were collected from under the trees in Uyo metropolis, Akwa Ibom State, Nigeria between 2016-2018. The fruits (Figure 1) were cracked to remove the seeds (Figure 2) and the seeds peeled to get the kernel (mesocarp) (Figure 3).

Figure 1. Sandbox fruits.

Figure 2. Sandbox seeds.

Figure 3. Sandbox kernels.

Sandbox oil (Figure 4) was extracted from the sandbox seed by solvent extraction method using AOCS 5-04 standard procedure. Methanol was used as the alcohol in the transesterification (Figure 5) of the oil in the presence of potassium hydroxide catalyst. The transesterification reaction was conducted at 60°C reaction temperature, alcohol-oil ratio of 1:5, catalyst concentration 0.9 g weight of oil and reaction time of 90 min. The methyl ester produced was separated from the glycerol phase and washed thoroughly. The SMBE (Figure 6) was blended with (AGO) at varying proportion, 5, 10, 15, 20, 25, 50 and 100%: diesel ratios, denoted as B100, B5, B10, B15, B20, B25, B50 and B100.

Figure 4. Sandbox seed oil.

Figure 5. Transesterification.

Figure 6. SBME.

Determination of fuel properties of sandbox methyl ester

The properties of the SBME produced were characterized using the ASTM standards (Table 2). The following properties of the biodiesel and its blends were determined; Density, Specific Gravity, Cloud Point, Pour Point, Kinematic Viscosity, Saponification Value, Acid Value, Free Fatty Acid Value, Iodine Value, pH value, Flash Point, Fire Point, Cetane Number, and Higher Heating Value (HHV). Automotive Gas Oil was used as control.

Table 2. Biodiesel standards and their corresponding ASTM Standards.

S/N	Property	ASTM Standard
1	Density	D941
2	Specific gravity	D1298
3	Cloud point	D2500
4	Pour point	D97
5	Flash and fire points	D93
6	Kinematic Viscosity	D445
7	Saponification value	D5558
8	Acid value	D664
9	Heating value	D40

Free Fatty Acid

The free fatty acid (FFA) of the fuel was obtained by the titration method used by Buhain and Guo (2013) for fresh vegetable oil and waste frying oil biodiesel. Two drops of phenolphthalein were added to 10 ml of isopropyl alcohol, 1 ml of fuel sample was then added and titrated with 1 g l^{-1} of NaOH in distilled water. A blank isopropyl alcohol was titrated and the volume of NaOH used recorded as V_1. The volume of NaOH used on that with fuel samples were recorded as V_2. The FFA content was calculated from Equation 1.

$$FFA\ (mg/g) = (V_2 - V_1) \times \frac{1.4}{d_{oil}} \quad (1)$$

Where d = density of fuel sample

Iodine value

A volume of chloroform with 2% volume of the fuel sample were titrated with Wiji's solution (5 ml), stirred carefully and kept in the dark for 3 min. After this, Potassium iodide solution (5 ml; 7.5%) was added and titrated using 0.1 N sodium thiosulphate solution until a color change was observed. Starch indicator (3 drops) was afterward added, and titration progressed to a colourless or milky. Results were calculated as $I_2/100$. Iodine values of the oil samples were calculated by the expression used by (Ogbunugafor *et al.*, 2011) as shown in Equation 2.

$$\text{Iodine value} = \frac{(V_b - V_s) \times 1.269}{M} \quad (2)$$

Where V_b = Titre value for blank, V_s = Titre value for sample and M = mass of sample in gram.

Cetane Number

The Cetane number of the biodiesel was determined by standard method from chromatography analysis of the free fatty acid contents of the biodiesel. The Philip's Pye-Unicam PU 4500 gas chromatography equipped with 30 m × 0.32 mm HP^{-5} column, stationary phase coating 0.50 µm. The column temperature was kept at 250°C for 2 min, with increase at 5°C per min up to injector temperature of 250°C, split ratio of 1:35, and carrier gas (Helium) flow rate of 1.8 ml min^{-1}. The SBME FFA compositions were identified by the Gc-Ms intensity and Equation 3, developed by Bamgboye and Hansen (2008) was used to calculate the Cetane number of the fuel.

$$CN = 61.1 + 0.088x_2 + 0.133x_3 + 0.152x_4 - 0.101x_5 - 0.039x_6 - 0.243x_7 - 0.395x_8 \quad (3)$$

Where x represents the free fatty acid compositions of the fuel

RESULTS AND DISCUSSION

Fuel properties of the sandbox seed methyl ester and blends are presented in Table 3. The fuel properties and the control AGO are presented in Table 4. The comparison of the SBME and ASTM standards are shown in Table 5. The free fatty acid composition of the SBME is as shown in Table 6.

Specific Gravity

The specific gravity increases with addition of SBME to AGO blend (B5-B100) from 0.87-0.82 (Table 3). The specific gravity of the SBME was 0.87, which was higher than the control (AGO) of 0.82 (Table 4). The specific gravity values were similar to 0.860 ± 0.015 obtained by Adepoju *et al.* (2013) for sandbox seed. Bamgboye and Oniya (2012) reported 0.89 for Loofah seed oil, and 0.85 for groundnut oil methyl ester (Oniya and Bamgboye, 2014). The specific gravity values obtained for the SBME was within the limit specified by various international standards, ASTM (Table 5) and EN14214 (0.85-0.90), ONC1191 (0.86-0.90), CSN656507 (0.85-0.89), Journal Officiel (0.87-0.89), DINV51606 (0.87-0.90), UN110635 (86-0.90) and SS155436 (0.87-0.90) respectively for biodiesel fuels (Bamgboye and Oniya, 2012). The low value of the specific gravity indicated a good ignition property for the sandbox seed biodiesel (Bello and Daniel, 2015).

Table 3. Characteristics of sandbox seed biodiesel.

S/N	Characteristics	Biodiesel blends						
		B5	B10	B15	B20	B25	B50	B100
1	Density, kg m^{-3}	865	878	880	884	890	888	891
2	Specific gravity	0.82	0.83	0.85	0.86	0.86	0.87	0.87
3	Kinetic viscosity, mm^2 s^{-1}	4.0	4.1	4.1	4.2	4.4	5.0	5.8
4	Flash point, °C	90	93	98	102	108	128	160
5	Fire point, °C	140	142	143	145	150	218	230
6	Pour point, °C	-9.2	-8.4	-7.5	-7.3	-7.0	-6.9	-6.8
7	Cloud point, °C	3.4	3.8	3.9	4.0	4.1	4.4	4.6
8	Cetane number							46.71
9	Heating value, MJ kg^{-1}	41.45	41.00	40.98	40.85	40.70	40.55	40.5
10	Saponification value, mgKOH g^{-1}	143	150	156	170	182	188	200
11	Acid value, mgKOH g^{-1}	2.2	2.4	2.4	2.5	2.5	2.5	2.7
12	FFA, mg g^{-1}	1.1	1.2	1.2	1.25	1.25	1.25	1.33
13	Iodine value, gI2 100g^{-1}	94	98	101	102	104	105	108
14	pH value	5.6	5.8	5.9	6.0	6.4	6.5	6.8
15	Ash content, g 100g^{-1}	0.16	0.12	0.10	0.06	0.06	0.02	0.01
16	Carbon content, wt%	85.62	85.21	84.56	84.01	83.55	81.99	80.02

Table 4. Properties of sandbox seed biodiesel and diesel (AGO).

S/N	Properties	Biodiesel	Diesel (AGO)
1	Density, kg m^{-3}	891	861
2	Specific gravity	0.87	0.82
3	Kinetic viscosity, mm^2 s^{-1}	5.8	3.8
4	Flash point, °C	160	88
5	Fire point, °C	230	135
6	Pour point, °C	-6.8	-9.6
7	Cloud point, °C	4.6	1.8
8	Cetane number	46.71	42
9	Heating value, MJ kg^{-1}	40.5	41.5
10	Saponification value, mgKOH g^{-1}	200	140
11	Acid value, mgKOH g^{-1}	2.7	2.0
12	FFA, mg g^{-1}	1.33	0.9
13	Iodine value, gI2 $100g^{-1}$	104.4	88
14	pH value	6.8	5.6
15	Ash content, g $100g^{-1}$	0.01	0.08
16	Carbon content, wt%	80.02	86.88

Table 5. Sandbox seed biodiesel characteristics against ASTM Standards.

S/N	Properties	SBME	ASTM Standards Biodiesel B100 D6751	ASTM Standards Diesel D975
1	Density, kg m^{-3}	891	820-845	
2	Specific gravity	0.87	0.88	0.85-0.90
3	Kinetic viscosity, mm^2 s^{-1}	5.8	1.9-6.0	1.3-4.1
4	Flash point, °C	160	130-170	60-80
5	Fire point, °C	230	315-350	180-340
6	Pour point, °C	-5.8	-15-10	-35-(-15)
7	Cloud point, °C	4.60	-3-12	-15-5
8	Cetane number	46.71	47-65	40-55
9	Heating value, MJ kg^{-1}	40.5	37.27	
10	Saponification value, mgKOH g^{-1}	200		
11	Acid value, mgKOH g^{-1}	2.7	0.5-0.8 max	
12	FFA, mg g^{-1}	1.33		
13	Iodine value, gI2 $100g^{-1}$	104.4	120	
14	pH value	5.10		
15	Ash content, g $100g^{-1}$	0.01	0.05 max	
16	Carbon content, wt%	80.02		
17	Heat Capacity, MJ K^{-1}	5.20		

Source: American Society for Testing and Materials, Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels, Designation D6751-07 (2007)

Kinematic viscosity

The kinematic viscosity of the sandbox methyl ester was 5.8 mm^2 s^{-1} and decreased with the addition of diesel in the blend (B100-B5) from 5.8-4.0 mm^2 s^{-1} (Table 3). In comparison, the viscosity values are within the range of 3.8 obtained for the control (AGO) (Table 4). The viscosity was higher than the 3.95 ± 0.20 obtained by Adewuyi *et al.* (2012) and 2.78 ± 0.02 mm^2 s^{-1} obtained by Adepoju *et al.* (2013) respectively for sandbox seed oil methyl ester. Indhumathi *et al.* (2014) obtained 9.1 mm^2 s^{-1} for methyl ester from green micro algae, while Bello and Daniel (2015) and Oniya and Bamgboye (2014) obtained 4.4 mm^2 s^{-1} and 7.60 mm^2 s^{-1} respectively for groundnut oil methyl ester. Kumar and Kant (2013) obtained 3.237mm^2 s^{-1} from sorghum oil biodiesel. Aladetuyi *et al.* (2014) obtained the values; 3.97, 4.03, 4.76 and 5.48 mm^2 s^{-1} respectively, for biodiesel from fresh palm kernel oil and palm kernel oil recovered from spent bleaching earth. The kinematic viscosity values of the biodiesel and its biodiesel blends are within the ASTM D6751 standard range of 1.9-6.0 mm^2 s^{-1} (Table 5). The range of viscosity obtained for sandbox, is an indication of high injection performance, as it would be easy to pump, atomize and to achieve finer droplets (Sivaramakrishnan and Ravikumar, 2012), as high kinematic viscosity values causes poor fuel atomization, incomplete combustion, and carbon deposition in injectors (Knothe and Steidley, 2005).

Flash Point

The flash point of the sandbox biodiesel was 160°C and decreased with the addition of diesel from B100 to 90°C for B5 (Table 3). The value was higher than 142°C obtained from the control (AGO) (Table 4). The flash point value was higher than 152 ± 1.1°C and 112°C respectively obtained by Adewuyi *et al.* (2012) and Adepoju *et al.* (2013) for sandbox seed methyl ester. These differences could be influenced by prevailing weather and environmental conditions. Bello and Daniel (2015) obtained 178°C for groundnut oil methyl ester, while Oniya and Bamgboye (2014) obtained 200°C for groundnut oil methyl ester. Sathiyagnanam and Saravanan (2011) obtained 150°C as flash point for cottonseed oil biodiesel. Rao (2011) obtained flash point of 170°C for *Jatropha* biodiesel. Varathan and Karuppasamy (2015) obtained 142°C as flash point for *Calophyllum inophyllum* (Honne) oil biodiesel. Neva Voca *et al.* (2008) obtained flash point of 157°C for rapeseed, 149°C for sunflower and 126°C for waste edible oil. Also obtained are; babassu; 127°C soybean; 178°C, sun flower; 96°C, peanut; 176°C, and palm; 183°C (Sivaramakrishnan and Ravikumar, 2012) and mustard seed oil; 120°C, coconut oil; 116°C, *Jatropha*; 185°C, micro algae; 115°C, soybean; 96°C, sesame; 170°C, karanja; 180°C, linseed oil; 161°C, rubber seed oil; 130°C and Neem seed oil; 245°C (Habibullah *et al.*, 2015). The sandbox seed biodiesel flash point is within the ASTM D6751 standard of (130-170°C) (Table 5). This flash point temperature of the fuel would guarantee safety during handling and transportation of the fuel.

Fire Point

The fire point of the sandbox seed oil methyl ester was 230°C and decreased with the addition of diesel in the blend (B100-B5) to 140°C (Table 3). In comparison, the fire point value was higher than that the control (AGO), 135°C (Table 4). The value is below the ASTM D9751 standards of (315-350°C) for biodiesels, but within the range for AGO (180-340°C) (Table 5). The low values of the fire point are indication of the combustion quality of the sandbox seed oil methyl ester. Sathiyagnanam and Saravanan (2011) obtained 161°C as fire points for cottonseed oil biodiesel.

Cloud Point

The cloud point of the sandbox seed oil methyl ester was 4.6°C and biodiesel decreased with the addition of diesel in the blend (B100-B5) from 4.6-3.4°C (Table 3). The cloud point value was higher than 1.8°C obtained for the control (AGO) (Table 4). The cloud point value was lower than 6°C obtained by Adepoju *et al.* (2013) as cloud point for sandbox seed methyl ester. Rao (2011) obtained 8°C for Jatropha seed oil biodiesel.

Cloud and pour points obtained by Neva Voca *et al.* (2008) for various biodiesel sources are rapeseed; -1°C and -7°C, sunflower; 0°C and -2°C and waste edible oil; -1°C and -5°C respectively. The cloud point is within the ASTM standards (Table 5), indicating a good cold temperature quality of sandbox seed methyl ester.

Pour Point

The pour point of the sandbox seed oil methyl ester was -6.8°C and decreased with the addition of diesel in the blend (B100-B5) to -9.2°C (Table 3). The pour point value was lower than -9.6°C obtained for the control (AGO) (Table 4). The value of the pour point obtained was lower than -15°C reported by Adepoju *et al.* (2013) for sandbox seed biodiesel. The effect of diesel addition to the cloud and pour point was the same as noted by Bamgboye and Oniya (2012) for loofah seed oil. The higher cloud and pour points of the biodiesels may entail a number of adverse effects on diesel engine when used during cold seasons. Cold temperature behavior of biodiesel is a vital quality criterion, as frozen fuel may cause obstruction of the fuel hoses and filters and limit fuel flow to the engine (Bello and Agge, 2012). The pour point is within the ASTM standards (Table 5), indicating a good cold temperature quality of sandbox seed methyl ester.

Heating Value

The heating value of the sandbox seed oil methyl ester was 40.5 MJ kg^{-1} and increased with the addition of diesel in the blend (B100-B5) to 41.45 MJ kg^{-1} (Table 3). In comparison, the value was so close to 41.5 MJ kg^{-1} obtained for the control (AGO) (Table 4) and above the ASTM standard (Table 5). Similarly, Adepoju *et al.* (2013) obtained 40.30 MJ kg^{-1} for sandbox seed oil methyl ester. The calorific value of biodiesel is what establishes it as suitable alternative to diesel fuels as fuel heating value is a determinant of its energy content releasable for doing work (Sivaramakrishnan and Ravikumar, 2012). The heating value as obtained for sandbox seed biodiesel positions it as a suitable fuel to run diesel engine on its own as a blend of diesel fuel. The calorific value shows a comparative advantage over known biodiesel sources such as *Jatropha* oil (34.7 MJ L^{-1}) (Barminas *et al.*, 2001), rapeseed (38.3), sunflower (38.2) and waste edible oil (37.5) (Neva Voca *et al.*, 2008), 38.51 MJ kg^{-1} and Neem seed oil; 40.1 MJ kg^{-1} (Habibullah *et al.*, 2015).

Cetane Number

The Cetane number for the sandbox methyl ester was 46.71 (Table 3). The approximated value of 47 fell within the ASTM D6751 standard (Table 5). The Cetane number value was higher than 42 obtained for the control (AGO) (Table 2). The Cetane number is within the range of 45.62 and 50.40 obtained by Adewuyi *et al.* (2012) and Adepoju *et al.* (2013) respectively for sandbox methyl ester. According to Bamgboye and Hansen (2008), Cetane number is an essential factor in determining the fuel quality of biodiesel. With 82.32% unsaturation (oleic, 23.10% and linoleic, 56.42%) (Table 6), the Cetane number of the sandbox biodiesel was within the Cetane number reported for pure linoleic acid, 36.8 and that of oleic acid, 57.2 (Bamgboye and Oniya, 2012). This is in agreement with findings made by Bamgboye and Hansen (2008) that Cetane numbers of esters of cottonseed, sunflower, rapeseed, soybean, canola, oil palm, peanut, lard and tallow oils were within the range of Cetane numbers of the dominating fatty acid content. The Cetane number of sandbox seed biodiesel is within the range of values reported for vegetable oils by Moreno *et al.* (1999); Bamgboye and Hansen (2008) for soybean (45-60), rapeseed (44-59), cottonseed (45-55).

Table 6. Fatty acid composition of Sandbox seed oil

S/N	Fatty acids	Sandbox seed oil methyl ester (% wt)	Saturation
1	Lauric (12:0)	-	Saturated
2	Myristic (14:0)	-	Saturated
3	Palmitic (16:0)	13.5	Saturated
4	Palmitoleic (16:1)	-	Saturated
5	Stearic (18:0)	4.13	Saturated
6	Oleic (18:1)	23.10	Unsaturated
7	Linoleic (18:2)	56.42	Unsaturated
8	Linolenic (18:3)	2.80	Unsaturated
9	Others	0.05	

Saponification Value

The saponification value of the sandbox seed oil methyl ester was 200 mgKOH g^{-1} and decreased with the addition of diesel in the blend (B100-B5) from 200-143 mgKOH g^{-1} (Table 3). However, with the addition of diesel fuel in the blend, the saponification value narrows closer to 140 mgKOH g^{-1} obtained for the control (AGO) (Table 4). The value is higher than the saponification value of 180.20 ± 0.10 mgKOH g^{-1} obtained by Adepoju *et al.* (2013) for sandbox seed oil methyl ester, 165 mgNaOH g^{-1} by Kumar and Kant (2013) for Sorghum oil, 191.32 and 170 mgKOH g^{-1} for groundnut oil by Bello and Daniel (2015) and Oniya and Bamgboye (2014) respectively.

Acid Value

The acid value of sandbox methyl ester was 2.7 mgKOH g^{-1} and biodiesel decreased with the addition of diesel in the blend (B100-B5) from 2.7-2.2 mgKOH g^{-1} (Table 3). The value is higher than 2.0 mgKOH g^{-1} obtained for the control (AGO) (Table 4). The value is higher than 0.21 ± 0.00 and 2.34 ± 0.15 mgKOH g^{-1} obtained by Adewuyi *et al.* (2012) and Adepoju *et al.* (2013) respectively for sandbox seed methyl ester. 0.43 and 5.31 mgKOH g^{-1} acid value was obtained for Sorghum and Jatropha biodiesel respectively (Kumar and Kant 2013). The value fell short of ASTM standard (0.5-0.8) (Table 5).

Other Parameters

The FFA content was 1.33 (Table 3). The value is higher than 1.17 ± 0.02 mg g^{-1} obtained by Adepoju *et al.* (2013) for sandbox seed biodiesel. Aladetuyi *et al.* (2014) reported 6.21 and 0.80 mg g^{-1} for fresh and recovered spent bleaching earth palm kernel oil. The Iodine value was 108 gI_2 $100g^{-1}$ (Table). The value was below the ASTM standard of 120 gI_2 $100g^{-1}$ (Table 5). It is also lower than 119.50 ± 0.50 and 116.40 ± 1.40 gI_2 $100g^{-1}$ obtained for sandbox seed methyl ester by Adewuyi *et al.* (2012) and Adepoju *et al.* (2013) respectively. Other properties determined were pH value of 6.80, ash content; 0.01 g $100g^{-1}$ and carbon content; 80.02 wt%.

CONCLUSION

Fuel properties of sandbox seed methyl ester (SBME) and its blends with diesel (AGO) have been determined. The properties of the SBME were found to fall within the ranges specified by various international standards for biodiesel fuels. The properties determined, indicate that SBME possesses good flow, ignition and combustion characteristics and cold temperature qualities that would guarantee safety during cold seasons, handling and transportation of the fuel. Relatively to diesel, SBME can thus be employed either in its pure form or blends with diesel to power compression ignition engines with little or no modifications.

DECLARATION OF COMPETING INTEREST

The author declares that she has no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The author is responsible for all parts of this article.

ETHICS COMMITTEE DECISION

This article does not require any ethical committee decision.

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