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Comparative Analysis of Oil Obtained from Moringa and Neem Seeds

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ABSTRACT

This study reports the extraction of oil from moringa and neem seeds using soxhlet extractor and the production of biodiesel from the two oils extracted and compared with fossil diesel in terms of physico-chemical properties and cost of production. The biodiesels were produced by transesterification reaction with alcoholic KOH at 90^0C temperature. From the results obtained it was found that the yield of biodiesel from moringa seed oil (48%) is less when compared with that neem seed oil (52%). It was found that the chemical properties of moringa and neem oils were, such as saponification, (196, 182) iodine value, (62.51, 83.4) specific gravity (0.71, 0.94) peroxide value, (1.22, 1.07) acid value, (0.62, 0.47) density, (0.72, 0.81) viscosity, (2.3, 4.2) when compared with the ASTM D 445 standard limit. The physical properties of the raw extracted oil and the biodiesel produced for moringa, neem and fossil diesel for flash point (149°C, 111°C, and 97°C), pour point (8°C, 5°C and 7°C) and cloud point (16°C, 9°C and 7°C) comparatively with the standard fossil fuel. The FT-IR result revealed the presence of SP^3 C-H (stretch) at 2923.81 cm^{-1}, C=O stretching vibration at 1746.67 cm^{-1} indicating the presence of carbonyl group, stretch vibrations at 3007.32 cm^{-1} showing the presence of aromatic SP^2 C-H. Also HC=O stretching at 2853.67 cm^{-1} was observed indicating the presence of aldehyde, the presence of HC =CH bend at 667.24 cm^{-1} indicates the presence of alkenes. The peak observed at 3564.19 cm^{-1} indicates the presence of O-H, the peak observed at 1195.50 cm^{-1} was assigned to C-O bend indicating the presence of carboxylic acid/esters. The moringa biodiesel contain more of fatty acids and the neem biodiesel contain more of esters due to esterification of the neem oil as revealed by through GC-MS spectrum of the neem oil. The neem oil cannot contain fatty acid due to the absent of the O-H (stretch) band on its FT-IR spectrum. The relative quantification was obtained from the chromatogram of both oil in GC-MS spectrum. The result showed that neem oil could be uses as an alternative to fossil diesel if large scale of production is employ.

Keywords: FTIR, Biodiesel, Oil, Fossil

INTRODUCTION

In this age of climate change, a lot of attention has been paid to environmental degradation, global warming, and the ever-depleting fossil fuel resources. These have developed to become important global concerns, and Numerous techniques have been proposed to decrease the negative repercussions of emissions from fossil fuels (Moyo *et al*., 2021; Abubakar *et al.,* 2022). The most effective fuel to replace diesel is thought to be biodiesel, which is clean and renewable (Latchubugata *et al.,* 2018). Nowadays, biodiesel may be utilized as a sustainable option that considers both environmental and economic aspects. It is a less damaging, biodegradable fuel that comes from renewable sources (Yunus *et al*., 2013). This biofuel has several advantages over conventional diesel fuel, including a high cetane number, low smoke and particle emissions, low carbon dioxide and hydrocarbon emissions (Kumar and Kant, 2013). Carbon (IV) oxide, smoke, and unburned hydrocarbon emissions are all decreased. Vegetable oil's high density, viscosity, low calorific value, and non-volatility cause atomization issues, pumping challenges, and poor combustion inside the diesel engine's combustion chamber (Abubakar *et al.,* 2022).

By chemically reacting vegetable or animal fat with an alcohol like methanol, biodiesel is created as a substitute fuel for diesel engines (Abubakar *et al.,* 2020). Because it can be used in any compression ignition engine without modification, biodiesel has recently been recognized as the best alternative for replacing diesel fuel. Compared to diesel fuel, biodiesel has several advantages: it is liquid, portable, renewable, and contains less sulfur and aromatics. It is also more biodegradable (Demirbas, 2009; Abubakar *et al.,* 2022).

A tropical plant that thrives throughout the tropics, moringa is a member of the Moringaceae family. Out of the thirteen species in the genus Moringa, only one, *Moringa oleifera*, has received research and development attention. In antiquity, it held great worth. The oil from the seeds was extracted by the Romans, Greeks, and Egyptians, who used it for skin lotion and perfume. Plantations growing Moringa in West India exported oil to Europe in the 19th century for use in industrial lubricants and perfumes. Native to northern India's sub-Himalayan regions, *M. oleifera* is also known as the "drumstick tree" or "orseradish tree." Because of its many uses in agriculture, industry, and medicine, moringa is a versatile tree with enormous economic value (Yisehak *et al.,* 2011).

Neem seed, derived from the neem tree (Azadirachta indica), is well-known for its versatile applications in a variety of industries, particularly because of its high oil content (Eid, & Elmarzugi, 2017). Neem oil, extracted from the seeds, contains a variety of biologically active compounds, including azadirachtin, nimbin, and nimbidin, all of which have potent pesticidal, insecticidal, and medicinal properties (Kumar, *et al.,* 2018). Neem oil has been shown in studies to have significant antimicrobial and antifungal properties, making it a valuable ingredient in agricultural practices and pharmaceutical formulations (Eid, & Elmarzugi, 2017). Furthermore, its high fatty acid content, which includes oleic acid, linoleic acid, and palmitic acid, makes it ideal for skincare and hair care products (Gupta, *et al.,* 2019). The oil's diverse array of bioactive constituents highlights its significance in both traditional medicine and modern scientific research, positioning neem seed oil as a versatile resource with enormous potential across various domains (Gupta, *et al.,* 2019). Neem trees can grow up to 800 meters above sea level and tolerate mean annual rainfall of 450–1200 mm along with typical temperatures of 25–35 ºC. The objective of this study is to synthesize, evaluate, and contrast biodiesel derived from the oils of neem trees (*Azadirachta indica*) and drumsticks (*Moringa oleifera*).

MATERIALS AND METHODS

Chemicals and Reagents

All of the chemicals and reagents utilized in this study were of analytical grade. N-hexane, Acetic acid, Chloroform, hydroxide, Potassium iodide, Sodium thiosulphate, Iodine and Phenolphthalein

Sample Collection and Preparation

Fresh seeds of Neem and Moringa were collected from Arawa Gombe in Gombe State and were identified at the Department of Botany by a botanist in Gombe State University, Gombe. After three rounds of distilled water washing, the samples were dried for three weeks in the shade and then stored for later use.

Soxhlet Extraction

With minor modifications, the procedure outlined by Petal et al. (2011) and Akbar et al. (2009) was employed. Weighed and put into a Soxhlet extractor was 500.00 g of the ground seed. With n-hexane serving as the solvent, the oil extraction process for eight hours. To eliminate any potential residual solvent in the oil extracted, the extracts were heated to 70 °C in an oven and allowed to air dry. The oil was weighed, and using a dry matter method, the percentage of oil yield was determined as follows:

$$\textbf{Percentage of oil yield} = \frac{\textbf{weight of oil}}{\textbf{weight of sample on dry matter basis}} \times \mathbf{100} \qquad -1$$

Production of Biodiesel Fuel

One gram of potassium hydroxide was weighed and placed in a 250cm^3 conical flask. A 120 cm^3 of methanol was added to the KOH pellets and then stirred until all the solid catalysts were dissolved using a magnetic stirrer while heating at about 60 °C on a hot plate. About 20.00 cm^{3}of the oil was measured using a measuring cylinder and heated to 60 °C for about 10 minutes. Then the 10 cm^3 potassium methoxide was quantitatively added into the heated oil. The mixture was agitated vigorously for about one minute in conical flask. After agitation, the mixture was continuously and gently stirred with a magnetic stirrer for 2 hours. The mixture was then transferred into a separating funnel that was clamped on a retort stand for 24 hours. After separation the lower layer was decanted off leaving the top biodiesel layer. The next step was washing of the biodiesel. This was carried out to remove excess methanol, KOH, soap and escaped glycerol. Distill water was progressively swirled into the crude product. This was allowed to stand for two hours. The lower water layer was run off, resulting in a clear biodiesel product. The resulting biodiesel was golden yellow in colour. The biodiesel yield was calculated using:

$$\textbf{Oil recovery} = \frac{\textbf{Volume of biodiesel collected} \times \mathbf{100}}{\textbf{Volume of sample oil}} - \quad - \qquad 2$$

Properties of Free Fatty Acids Methyl Esters (FAMEs)

Jauro, A. and Haruna, A.M. (2011) and AOAC (2023) methods were adopted with slight modification for the analysis of FAMEs unless otherwise stated.

Determination of free fatty acid (FFA)

A 1.00 g of Moringa and Neemseed oils were measured separately and placed into a 250 cm^3 conical flask and warmed. Methanol (10.00 cm^3) was added thorough stirring followed by 2 drops of phenolphthalein indicator. The content was titrated with 0.20 mol/dm^{3}NaOH until a light pink colour which persisted for 1 minute was seen.

The end point was recorded and used in calculating the FFA as follows:

$$\text{FFA} = \frac{\textit{Titre value x}\ \mathbf{M\ x\ 28.2}}{\textbf{Weight of sample}} \qquad - \quad - \quad -1$$

Where; M = concentration of the base in mol/dm^3 of the base, 28.2 is a constant

Determination of the peroxide value of the oil

One (1.00 g) of Moringa and Neemseed oil were weighed separately into a 250 cm^3 conical flask and 30.00 cm^3 of glacial acetic acid/chloroform (3:2 V/V) was added. The mixtures were shaken until they dissolved. Saturated potassium iodide (1 cm^3) was added then followed by the addition of 0.50 cm^3 starch indicator.

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This was titrated with 0.20 mol/dm^3 $Na_2S_2O_3$ until the dark blue colour just disappeared. Blank determination was also carried out and the peroxide value was calculated as follows:

$$P.V = \frac{(S-B) \times 1000 \times C}{W} \quad - \quad - \quad -2$$

Where S= titre volume of sample, B= titre volume of blank, C= concentration in mol/dm^3 of sodium thiosulphate solution, W= weight of oil sample, 1000 is a constant.

Determination of refractive index

The refractive index of the oils were determined using refractor meter by exposing the oil to the meter.

Determination of specific gravity of biodiesel

A makeshift specific gravity bottles were cleaned, soaked in acetone, and dried in an oven. The bottles were placed in a desiccator and let to cool to room temperature. After, the weight of the washed bottles were observed. The weights of the water-filled bottles were calculated. After that, the water was transferred into a beaker, acetone was then used to cleaned the bottle, and it was dried. The specific gravity of the biodiesel sample was measured by repeating the same procedure

$$\text{Specific gravity} = \frac{W1-W2}{W3-W2} \quad - \quad -3$$

Where; W_1= bottle weight + oil, W_2 = empty bottle weight, W_3 = equal volume of water + bottle weight.

Determination of density of the biodiesel

A makeshift bottle for specific gravity was cleaned and rinsed with acetone before being oven dried. In a desiccator, the bottles were allowed to cool to room temperature , and the empty bottle's weight was calculated using a weighing scale. The weight of the bottle containing biodiesel was recorded. The volume of the oil in the bottle was also measured, and the density was calculated as follows: (Ugah *et al.,* 2007).

$$\text{Density} = \frac{(\text{weight of bottle+oil}) - \text{weight of empty bottle}}{\text{Volume ofoil}} \quad - \quad -4$$

Determination of kinematic viscosity of the biodiesel

An innovative approach was utilized to determine this parameter as reported by (Abubakar *et al.,* 2020). The biodiesel was poured into the clamped burette and allowed to drain freely into a beaker. The time of flow was observed, and the kinematic viscosity was determined as follows:

$$\text{Kinematic viscosity} = \frac{\text{volume of the burette}}{\text{Time}} \quad - \quad -5$$

Determination of pH of the biodiesel

The biodiesel (10.00 cm^3) was measured into a 50 cm^3 beaker, the electrode of the meter was cleaned and dried, it was then placed into the sample and the measurement was recorded. (Schinas *et al.,* 2008).

Determination of flash point

This determination was made using an improvised method. A 50 cm^3 beaker was filled to a certain level (10.00 cm^3) with biodiesel, which was then heated on the hot plate at a consistent rate. The flash point was defined as the lowest temperature at which the test flame ignited the vapour above the sample. It was repeated three times, and the average was determined (Abubakar *et al.*, 2020).

Determination of cloud point

This parameter was estimated using an improvised method. A cylindrical test tube was filled with biodiesel to a certain level

(10.00 cm^3) and clamped with a clamp containing a thermometer. The test tube was placed in the ice bath, and the setup was checked periodically for cloud formation. The cloud point was determined by the temperature at which a definite cloud developed at the bottom of the test tube (Abdulkareem *et al.,* 2012).

Determination of pour point

This parameter was estimated using an improvised method. A cylindrical test tube was filled with biodiesel to a certain level (10.00 cm^3) and secured with a clamp that held the thermometer. In the ice bath, the sample was allowed to drop to temperatures lower than 0 ^{0}C. At this point, it was removed and tilted on the clamp while the setup was observed periodically. The pour point was observed by the lowest temperature at which the biodiesel was flow (Abubakar *et al.,* 2020).

Determination of cetane number (ASTM D 613)

Cetane Number: The cetane number was calculated as

$$\mathbf{CN} = \frac{\mathbf{46.3+5458\ X\ I.V}}{\mathbf{S.V-0.225}} \quad - \quad -6$$

Where: CN = Cetane Number, SV = Saponification value, IV = Iodine value (Dagde, 2019).

FT-IR

SHIMADZU FTIR-8400S FTIR machine was used for the Infrared analysis of the fossil fuel and the biodiesel obtained.

RESULTS AND DISCUSSION

Table 1: Physicochemical properties of Neem and Moringa seed oil

Parameters	Neem Oil	Moringa Oil	Standard Values	Limit
Moisture content (%)	2.3 ± 0.33 ^{a}	2.6 ± 0.32 ^{a}		
Colour	Golden-yellow	Golden-black		
Oil Yield (%)	52± 0.2^a	48± 0.01^b		
Saponification value (mgKOH/g)	162 ± 0.3 ^{a}	196 ± 0.1 ^{b}		189-198
Iodine value (gI$_2$ /100 g)	104 ± 0.02 ^{a}	98 ± 0.04 ^{b}	ASTM D4607max	≥ 130
FFA (mgKOH/g)	0.51 ± 0.09 ^{a}	1.09 ± 0.043 ^{b}		25
Refractive index (35 ^{o}C)	1.73 ± 0.01 ^{a}	1.28 ± 0.01 ^{a}		
Specific gravity	0.94 ± 0.01 ^{a}	0.71 ± 0.01 ^{a}	ASTM D6751	0.92
Peroxide value (meq/Kg)	1.07 ± 0.02 ^{a}	1.22 ± 0.02 ^{a}		2-10
PH value	6.79 ± 0.3 ^{a}	6.41 ± 0.2 ^{a}		
Acid value (mgKOH/g)	0.47 ± 0.2 ^{a}	0.62 ± 0.01 ^{b}	ASTM D6751	0-0.8
Density (g/cm^3)	0.80 ± 0.01 ^{a}	0.86 ± 0.01 ^{a}	ASTM D1298	0.86-0.90
Viscosity 35 ^{o}C (cm^3/sec)	2.3 ± 0.1 ^{a}	4.9 ± 0.3 ^{b}	ASTM D445	1.9 – 6.0

Key: a = significant difference, b = no significant difference.

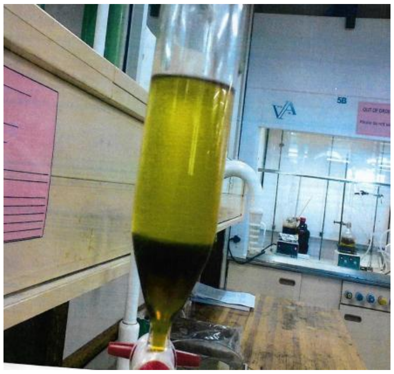

Figure 1: Pictures of the obtained oil from Moringa seed

Figure 2: Pictures of the obtained oil from neem seed

Results of the physicochemical characteristics of Neem *and Moringa* seed oils were presented in Table 1. The colour of the neem seed oil is golden-yellow while Moringa seed oil is golden-black in colour as shown from the figure 1 and 2 above and had the viscosity of (2.3 mm^2/s and 4.2 mm^2/s) for neem and moringa oil. The percentage yield of the oils where 52% and 48% for Neem and Moringa seeds oil respectively, this is larger than the percentage yields of *Z-spinachisti* (Nabag) seed crude oil. (28.96) as reported by Saeed and Abbas (2016), *J. gossyypiifolia* and *Jatropha curcas L.* (23.04 and 31.00) respectively as reported by Jefferson *et al.* (2009), and mustard seed oil (44.67), canola seed oil (43.87) corn seed oil (4.23) cotton seed oil (17.83) as reported by Arif *et al.* (2012) and it is within the A.O.A.C 1990. This high percentage oil yield indicates its potential use in detergent/ soap making industries and edible purposes (Abubakar *et al.*, 2020).

The saponification value of the Neem seed oil is 162.00 mgKOH/g, which is lower than that of Moringa oils 196 mgKOH/g. This is lower than *Jatropha curcas* seed oil (212.67 mgKOH/g) as reported by Abubakar *et al.* (2022). The Neem oil has showed a lower saponification value than Bebra seed oil (184.95 mgKOH/g) and Terminalia mantaly seed oil (196 mgKOH/g) as reported by Abubakar et al. (2020), and Z-spinachisti (Nabag) seed crude oil (183.39 mgKOH/g) as reported by Saeed and Abbas (2016). Moringa has a greater saponification value than sesame seed (192.70 mgKOH/g) and watermelon seed (192.09 mgKOH/g) as reported by Saeed and Shola (2015). Moreover, lower than bitter kola seed oil (229.45 mgKOH/g) and melon seed oil (247.0 mgKOH/g) as reported by Saeed and Shola (2015). This shows that there is a significant difference between mean values of Moringa and Neem oils. Hence, the lower the saponification, the higher the propensity of the biodiesel; conversely, the higher the saponification value, the lower the biodiesel; this suggests that moringa is preferable to neem in the creation of biodiesels.

The iodine value of Neem and Moringa were 104 $gI_2/100g$ and 98 $gI_2/100g$ respectively, which is higher than bitter kola 53.99 $gI_2/100g$, *Terminalia Catappa* (54.567 gI_2 /100g) and 44.4 $gI_2/100g$ cashew nut oil as reported by Aremu *et al*. (2006), and *J. curcas L*. (40.91 $gI_2/100g$) as reported by Abubakar *et al*. (2020). On the other hand, the Iodine value of this study is lower than the range of soyabean (128-143 $gI_2/100g$) as reported by Karmakar *et al*. (2017). The iodine value could be used to assess the quantity of double bond present in the oil, indicating the oil's vulnerability to oxidation. Oils with iodine value less than 100 $gI_2/100g$ of oil are non-drying oils, correspondingly, Aremu *et al*. (2006a), A good drying oil should have an iodine value of 130 or higher (Ebenezer, 2015). Biodiesel made from the same oil should have identical iodine values (Encinar 2010). It is related to the chemical composition of the fuel. A higher iodine value suggests more unsaturated fats and oils. The standard iodine value for biodiesel is 120, according to European EN 14214 regulations. This requirement is limited by the standard limits of linolenic acid methyl ester composition for biodiesel. The limiting of unsaturated fatty acids is important because heating more unsaturated fatty acids causes polymerization of glycerides. This can result in deposits or impairment of the lubricating property. Fuels with this property are also likely to form thick sludges in the sump of the engine, as fuel leaks down the sidewalls of the cylinder into the crank (Refaat 2010). As a result, there is a significant discrepancy in the average values of Neem and Moringa oils.

Moringa oil had a higher viscosity (2.3 cm^3/sec) than neem oil (4.9 cm^3/sec). Viscosity describes a fluid's internal resistance to flow and can be interpreted as a measure of fluid friction in optics to determine the rheological properties of these oils. When the temperature rises, the viscosity drops exponentially. Viscosity increased with molecular weight, but declined with rising unsaturation level and temperature (Akbar *et al*., 2009).

In this study, the acid value of Neem oil was 0.47 mgKOH/g, which is greater than 0.62 mgKOH/g for Moringa and lower than 13.76 mgKOH/g for J. curcas as reported by Abubakar et al (2022). This is higher than T. mantaly seed oil (0.56 mgKOH/g) and Bebra seed oil (0.052 mgKOH/g), as reported by Abubakar et al (2020). The acid value of Neem seed obtained from this study is higher than that of Terminalia belerica seed oil (3.69 mgKOH/g) and Sunflower oil (0.5-5.0 mgKOH/g), but similar to Lin seed oil (6.0 mgKOH/g) by Hossain et al (2007). The acid value of Neem surpasses the limit of A.O.A.C. Standard of <4.0, but Moringa is within the range. According to Aremu et al. (2015), high acid value in oil indicates that the oil may not be suitable for use in cooking (edibility), but could be beneficial for the creation of paints, biodiesel, liquid soap, and shampoo (Aremu et al., 2006a).

The peroxide value of Neem oil was found to be 1.07 mEq/Kg in this study, which is lower than 1.22 mEq/Kg for Moringa seed oil and lower than that of T. mantaly (4 mEq/Kg) and Terminalia catappa (2.60 mEq/Kg), as reported by Abubakar et al (2020). And Malaysian and Indian Jatropha (1.93 mEq/Kg) and (3.70 mEq/Kg), and similar to (1.08 mEq/Kg) for Thailanian Jatropha, respectively reported by Emil et al. (2010), and also lower than that of Moringa seed (5.82 mEq/Kg), sesame seed (8.33 mEq/Kg), Bitter kola (10.22 mEq/Kg), Melon seed (7.19 mEq/Kg), and water melon seed (13.41

mEq/Kg). The value meets the AOAC 1990 standard (Saeed and Shola, 2015).

The peroxide value is the most prevalent biomarker of lipid oxidation. Unrefined vegetable oils have higher PV than refined oils. High PVs indicate high levels of oxidative rancidity in the oils, as well as the lack or low quantities of antioxidants (Aremu et al., 2015).

In this study, the density of Neem seed oil is 0.81 g/cm3, which is greater than that of Moringa oils (0.72 g/cm3), but lower than the density of Jatropha podagrica seed oil (0.90 g/cm3) reported by Premjet et al. (2021), Tropical almond seed oil (0.90 g/cm3) reported Orhevba et al. (2016) Terminalia mantaly seed oil (0.92 g/m3) reported by Abubakar et al. (2020); Jatropha curcas seed oil (0.90 g/cm3) reported by Emil *et al.* (2010) soybean and sunflower (0.91 g/m3 and 0.92 g/m3, respectively), as well as the Bebra seed oil density of 0.94 g/m3 reported by Akpan et al. (2007). Vegetable oil has a lower density than water, and the variances amongst vegetable oils are minimal, especially among the most common vegetable oils. Generally, the density of oil decreases with molecular weight while increasing with unsaturation level (Gunstone, 2004; Ebenezer, 2015).

Neem oil has a specific gravity of 0.94, which is greater than Moringa seed oil's 0.71, but lower than that of sorrel and okra seed oils (1.00 and 0.90, respectively) as reported by Umar *et al*., (2020), and similar to Bebra seed oil (0.93) and cashew nut (0.96) reported by Aremu *et al.,* (2006) and castor seed oil (0.95) reported by Andualem and Gassesse (2014) but similar to that of Tropical almond oil (0.89) reported by Orhevba *et al.* (2016).

Table 2: Physico-chemical properties of moringa biodiesel, Neem biodiesel and fossil diesel.

Properties	**Moringa biodiesel**	**Neem biodiesel**	**Fossil diesel**	**Standard Values**	**Limit**
Flash point (^{o}C)	149 ± 7.0 ^{a}	111 ± 4.0 ^{b}	97 ± 4.0 ^{b}	ASTMD 93	100 – 170
Pour point (^{o}C)	8 ± 0.5 ^{a}	5 ± 0.3 ^{b}	3 ± 1.1 ^{b}	ASTMD 97	15 – 16
Cloud point (^{o}C)	11 ± 0.1 ^{a}	9 ± 0.2 ^{b}	7 ± 1.21 ^{b}	ASTMD 2500	3 – 12
Calorific value (mg/kg)	39.7 ± 3.5 ^{a}	25.1 ± 2.7 ^{b}	46.4 ± 2.9 ^{a}	-	-
Viscosity at 35^{o}C (cm^{3}/sec)	4.8 ± 0.3 a	4.1 ± 0.1 b	3.0 ± 1.0 c	ASTMD 445	1.9 – 6.0
Density (g/cm^{3})	0.87± 0.6 ^{a}	0.86± 0.8 ^{a}	0.89± 0.7 ^{a}	ASTMD 1298	0.88-0.90
Carbon residue (wt%)	7.1 ± 0.3 ^{a}	5.0 ± 0.2 ^{a}	10.0 ± 4.2 ^{b}	ASTMD 524	15 – 10
Cetane number	39 ± 0.5 ^{a}	43 ± 0.4 ^{a}	30 ± 0.1 ^{b}	ASTMD 613	47min

a = significant difference, b = no significant difference.

Moringa biodiesel has a flash point of 149 °C, which is greater than that of neem biodiesel and fossil diesels, which are 111 °C and 97 °C, respectively, which is lower than the 152 °C reported for J. curcas biodiesel by Abubakar et al (2020). Moringa has a greater flash point than Lageneria sicerria seed oil, according to Mahmoud et al. (2020), high-speed diesel (60-80 °C). Non-edible based seed oils have a greater flash point than fossil diesel (Kannahi and Arulmozhi, 2013). This demonstrates that there is a significant difference in the mean values of Neem and Moringa biodiesels, but no significant difference between Neem and fossil diesel at the 95% confidence level.

In this study, the pour point of Neem biodiesel was 8°C, higher than Moringa and Fossil biodiesels, which were 5°C and 3°C, respectively. This is greater than 0°C for J. curcas biodiesel, as reported by Lagenaria siceria biodiesel, 0°C, and -6°C and -9°C for castor oil biodiesel as reported by Mahmoud et al. (2020). The pour points of all biodiesels were almost within the desired range, although the conventional ranged from (Abubakar et al., 2020). This demonstrates that there is a significant difference in the mean values of Neem and Moringa biodiesels, but no difference between Neem and fossil biodiesels at the 95% confidence level.

Neem biodiesel, Moringa biodiesel, and Fossil biodiesel had cloud points of 11°C, 9°C, and 7°C, respectively, Abubakar et al. (2020) recorded a temperature of 4.56°C for J. curcas biodiesel, while Mahmoud et al. (2020) reported a temperature of 4°C for L. siceria biodiesel. All of the cloud points were within the standard, while the usual runs from -3 to -12, (Abubakar et al., 2020). This indicates that there is a significant difference between the mean values of Neem and Moringa biodiesels, but no difference between Neem and fossil biodiesels at the 95% confidence level.

The viscosity of Neem in this study is 2.1 cm^3/sec, which is lower when compared to that of Moringa and fossil diesel 4.8 cm^3/sec and 3.0 cm^3/sec respectively, and these are lower than 6.50 cm^3/sec as reported for L. siceria biodiesel as reported by Mahmoud et al. (2020) and higher than the viscosity of conventional D2 (at 40 °C) is between 1.9 and 6.0 cm^3/sec (ASTM, 2012). This demonstrates that there is a significant difference in mean values between Neem, Moringa, and fossil biodiesels at the 95% confidence level.

The density of Neem was determined to be 0.86 g/cm3, which is lower than that of Moringa and fossil diesels (0.87 g/cm3 and 0.89 g/cm3, respectively). This is lower than 0.96 g/cm^3 for T. catappa biodiesel reported by Orhevba et al., (2016), but close to 0.89 g/cm^3 reported by Jauro and Haruna (2011). It has a density similar to diesel (0.845 g/cm3) but is less dense than water. It can be used as an alternative fuel because it meets the ASTM criteria for biodiesel (0.86 - 0.92) g/cm^3. This indicate that there is no significant difference in mean values between Neem, Moringa, and fossil biodiesels at the 95 percent confidence level.

The cetane number (CN) determined in this study was 63 for Neem biodiesel, which is higher than 59 and 41 for Moringa and Fossil biodiesels, respectively. Moringa values are greater than those of avocado biodiesel 52.20 published by Dagde (2019), while Neem and Moringa values are higher than 51.70 reported for T. catappa biodiesel by Orhevba et al (2016). This demonstrates that there is no significant difference between the mean values of Neem and Moringa, but there is a significant difference between Neem and fossil biodiesels, as well as Moringa and fossil diesel, at the 95% confidence level. The cetane number is a measure of the fuel's ignition delay. Higher cetane levels suggest shorter periods between fuel injection and ignition.

FT-IR ANALYSIS

Neem and moringa biodiesel samples were analysed using FT-IR. The following functional categories were discovered in neem and moringa.

Table 3: Functional groups present in neem biodiesel

Wave number (cm^{-1})	Types of vibration	Nature of functional Group
3500.04	O-H (Bonded)	Carboxylic/alcohol
1746.67	C=O (stretch)	Aldehyde/ketone /ester
2853.67	H-C=O (stretch)	Aldehyde
2923.81	C-H (Stretch)	Alkanes
3007.32	C-H (stretch)	Aromatic
1463.79	C –H (bend)	Alkanes
1163.48	C-O (stretch)	Esters / alcohol / ethers
667.24	C–H (bend)	Alkynes

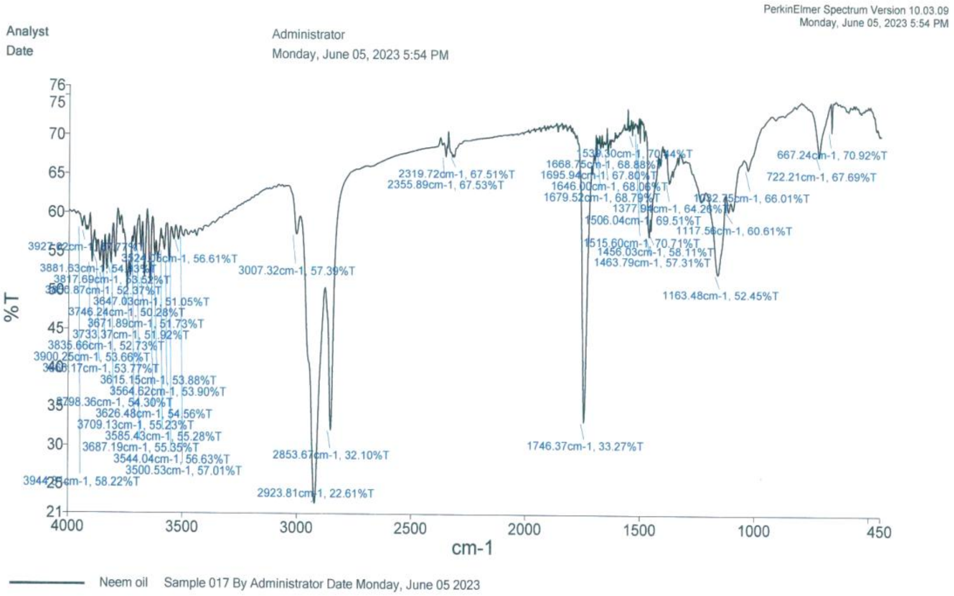

Figure 3: FTIR spectrum of Neem biodiesel

The FT-IR results were given in table 3 and the FTIR spectrum on figure 3. The FT-IR measurements show the presence of C-H (stretch) at 2923.81 cm^{-1} for alkanes. The C=O stretching vibration at 1746.67 cm^{-1} indicates the existence of esters/ketones. C-H stretch vibrations at 3007.32 cm^{-1} indicate the existence of aromatics. C-H bending at 1463.79 cm^{-1} suggests the existence of alkanes. Aldehyde is indicated by HC=O stretching at 2853.67 cm^{-1}, while alkenes are indicated by HC=CH bend at 667.2 cm^{-1}. This result was consistent with the literature results C-H stretch (~2900 cm−1), C=O stretch (~1700 cm−1), broad O-H stretch (~3400 cm−1) and C-O stretch (~1100cm−1) 886 cm^{-1}, 1436 cm^{-1} and 1644 cm^{-1} as reported by Snezana *et al.,* (2020). Also absorption were observed at 2923.81 cm^{-1} indicating alkyls (CH_3, CH_2, CH), 1722.68 cm^{-1} indicating ketone, 1598.10 cm^{-1} indicating alkenes and 1374.83 cm^{-1}Methyl CH_3 (Ogwuche and Edema, 2020). And also similar to what has been reported by Elkady *et al.,* (2015) 721 cm^{-1} -CH_2 rocking, 1373.7 cm^{-1} Bending vibrations of CH_2 groups, 1745 cm^{-1} C=O ester stretch, 1163 cm^{-1} C-O stretching, 1456 cm^{-1} Bending vibrations of the CH_2, 2925 -CH_2 stretching.

Table 4: Functional groups present in *moringa* biodiesel

Wave number (cm^{-1})	Types of vibration	Nature of functional group
3564.19	O-H (stretching)	Phenol/ alcohol
2681.95	HC=O (stretch)	Alkanoic acid/ aldehyde
3019.6	C-H (stretch)	Alkanes
1755.26	C=O (stretch)	Esters
1463.09	C-H (bend)	Alkane
1372.51	C-H (rock)	Alkanes
1169.52	C=C (stretching)	Alkenes
2845.7	C-H (stretch)	Alkanes

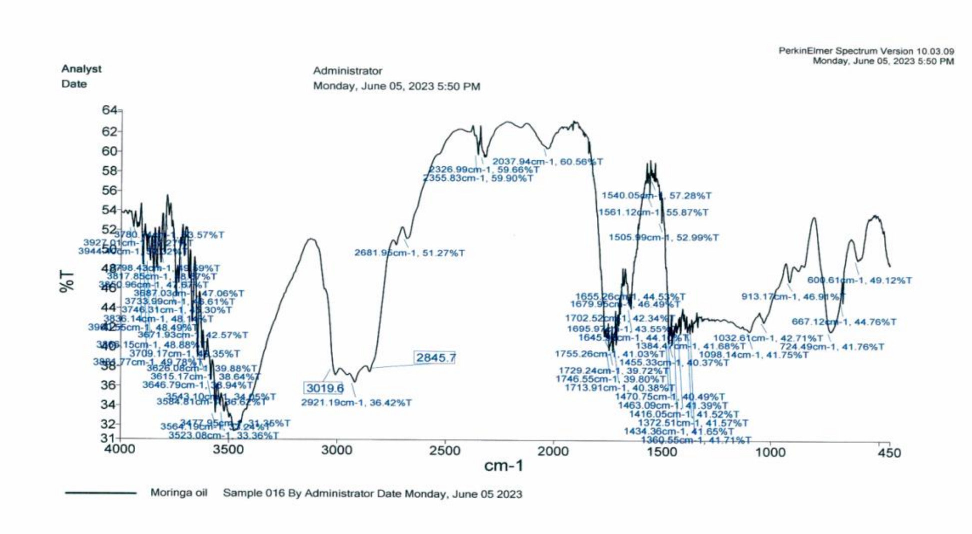

Figure 4: FTIR Spectrum of Moringa biodiesel

The FT-IR data were presented in Table 4 and the FTIR spectrum on figure 4. The signal at 3564.19 cm^{-1} indicates the existence of Stretching phenol/alcohol O-H. The HC=O (stretching) at 2681.95 cm^{-1} indicates the existence of aldehyde. The C-H stretching vibration at 3019.6 cm^{-1} suggests the existence of alkanes. C-H bending vibrations at 1463.09 cm^{-1} indicate the existence of alkanes, whereas C-O bend at 1195.50 cm^{-1} indicates the presence of carboxylic acid, esters/alcohol. C=C stretch at 1169.52 cm^{-1} indicates the presence of alkenes; C-H (rock) stretch at 1372.52 cm^{-1} indicates the existence of alkanes; and C=O stretch at 1755.26 cm^{-1} indicates the presence of ester. This result is consistent with previous results for C-H stretch (~2900 cm^{-1}), C=O stretch (~1700 cm^{-1}), broad O-H stretch (~3400 cm^{-1}), and C-O stretch (~1100 cm^{-1}) as reported Snezana *et al*., (2020).

The FT-IR results show that moringa biodiesel contains more fatty acids than neem biodiesel, which contains more esters due to esterification of the fatty acid in neem oil. Neem oil cannot contain fatty acids because it lacks the O-H (stretch) band on its FT-IR spectrum. So, the GC-MS results of both the neem and moringa biodiesel indicated the presence of undecanoic acid in moringa oil but not in neem oils.

GC Result of Neem and moringa biodiesel

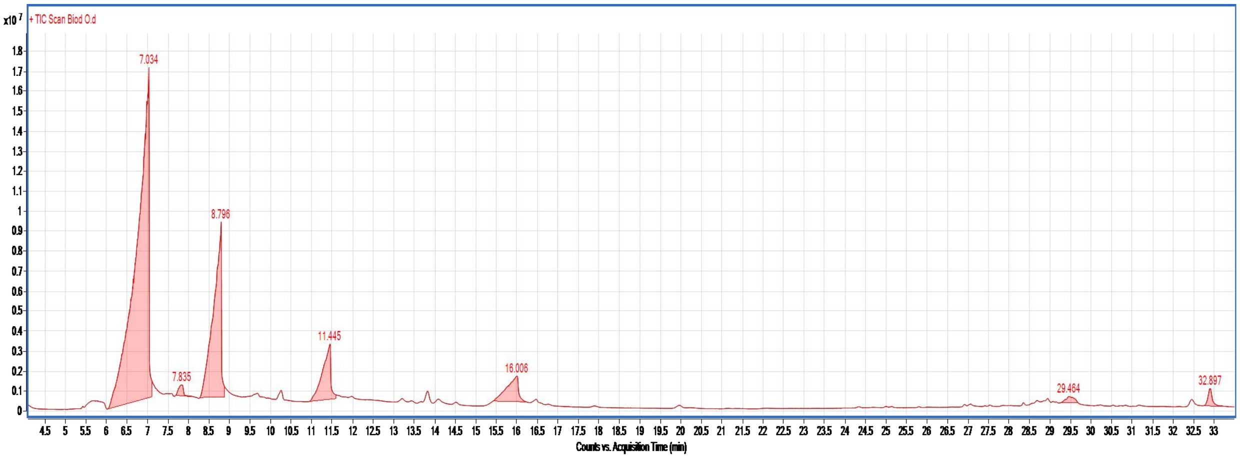

Figure 5: Chromatogram of neem biodiesel

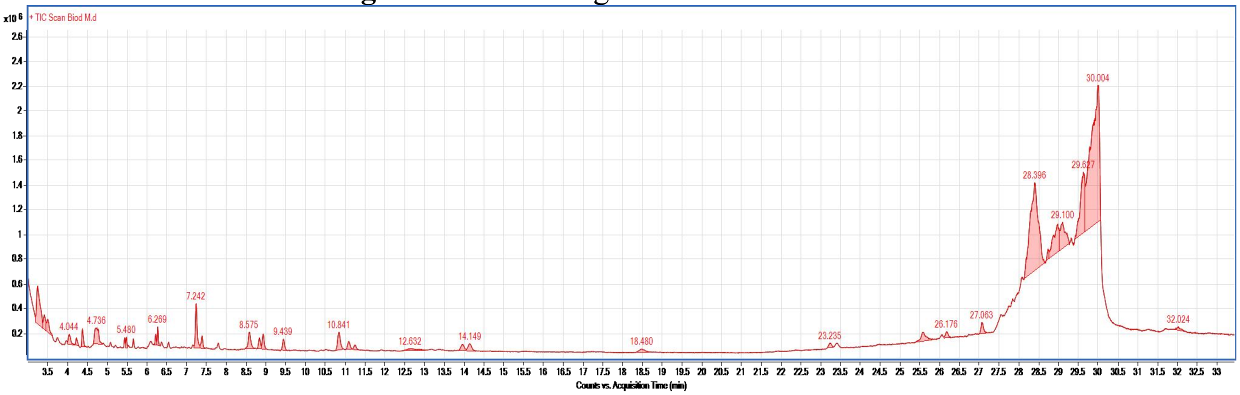

Figure 6: Chromatogram of Moringa biodiesel

The chromatogram for both neem and moringa biodiesel were presented on figure 5 and 6 respectively they all have many peaks but there relative quantification were shown below.

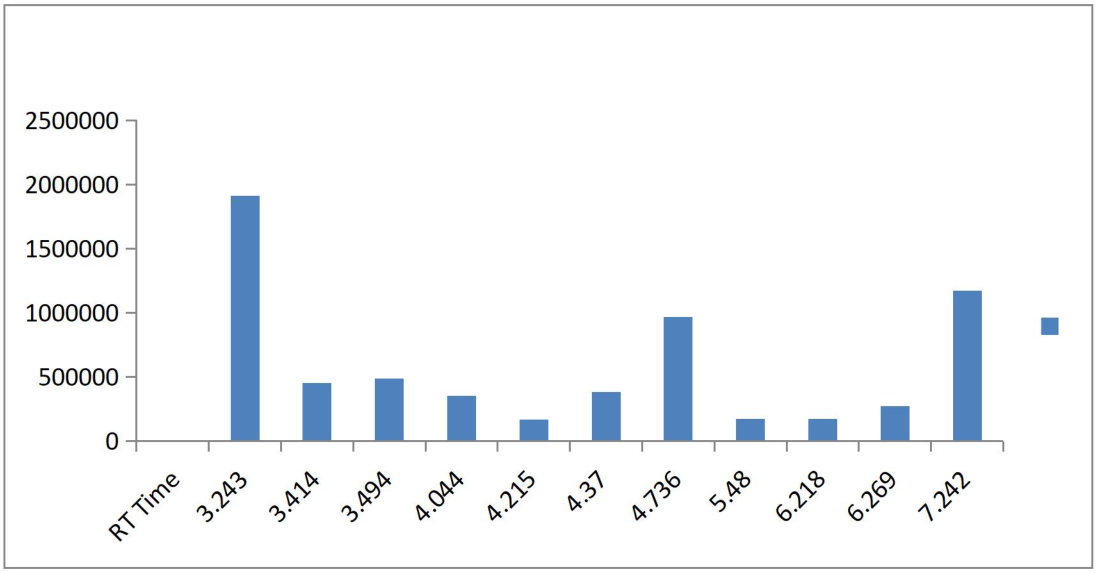

Figure 7: Relative quantification of neem biodiesel

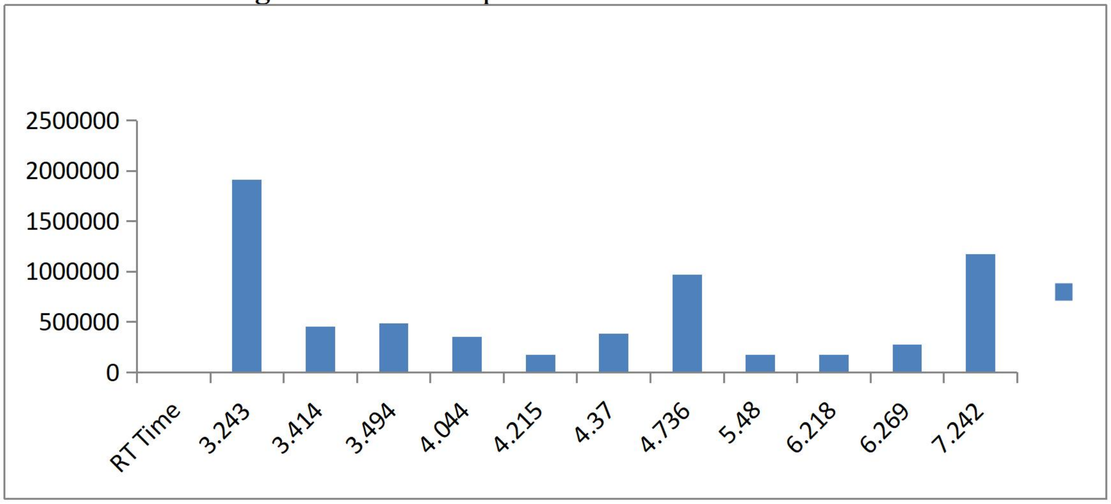

Figure 8: Relative quantification of moringa biodiesel

From the above data obtained in the GC-MS analysis as from in figure 5, 6, 7 and 8. The compound with the highest concentration is the oleic acid for the undecanoic acid. While the compound with the highest concentration is the methyl-12-methyltetradecanoate ester. The relative quantification is obtained from the chromatogram of both biodiesel in the GC-MS spectrum.

CONCLUSION

This study describes the synthesis, characterisation, and comparison of biodiesels made from Neem and Moringa seed oils, with the goal of obtaining the highest output possible. Moringa and Neem biodiesel yielded 69.80% and 63.40%, respectively. The study found that neem seed oil might be used as a substitute for fossil oil. Producers must carefully analyze and alter their operations to preserve biodiesel quality and efficiency in the face of feedstock changes.

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