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Studies on *Cucurbita maxima* Seed Oil for its Potentials as Feedstock for Biodiesel Production in Nigeria

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ABSTRACT

This research studied the potentials of the seed oil of *Cucurbita maxima* for biodiesel production. The oil was extracted using soxhlet extractor with n-hexane as a solvent and pretreated by degumming and then transesterified to biodiesel. The results obtained showed high percentage oil extraction of 42.13 ± 0.1% and percentage degumming of 7.6 ± 0.1%. The oil showed high acid value of 8.415 ± 0.8 mgKOH/g, which indicated high free fatty acid content and the percentage yield of the biodiesel produced was 96.78 ± 0.9%. Fuel properties (colour, cetane, flash point, cloud point, pour point, sulphur content, kinematic viscosity and specific gravity) determined showed compliance with American Standard Testing and Material (ASTM) and European standard specifications. The profile of methyl esters showed that unsaturated oleic acid methyl ester was dominant. The results suggested that *Cucurbita maxima* seed oil possesses some properties that were suitable for biodiesel production.

Keywords: Biodiesel, methyl esters, degumming, transesterification, *Cucurbita maxima*

INTRODUCTION

The depletion of the world's petroleum reserves, global warming and environmental degradation caused by exploration of oil calls for alternative energy sources to petroleum based fuels. One possible alternative to fossil fuel is the use of biodiesel which is a renewable fuel, non-toxic, safer to handle, biodegradable, requires no engine modifications and reduces dependency on foreign oil imports [1]. The search for alternative fuel for diesel engines has been focused on vegetable oil, because of its renewable sources from agriculture and the fact that it is abundantly available and distributed all over the world [2]. Attempts to use vegetable oils to fuel diesel engines gave rise to problems mainly due to high viscosities, different chemistry of combustion, and lubrication oil contamination due to incomplete combustion [3]. The differences in chemistry of combustion is manifested in the form of poor cold flow properties, poor atomization, coking tendencies, carbon deposits, cold starting problems, and wear in direct injection engines [3]. Thus giving rise to the need for a method of converting vegetable oil to esters which is generally called biodiesel [4]. One of the most viable method for overcoming the disadvantages of vegetable oil is to convert to esters by transesterification process. Transesterification results into the formation of mono-alkyl esters called biodiesel with glycerol as by-products [5, 6]. Transesterification reduces the molecular weight and the viscosity while also increasing the volatility but maintains the cetane number and heating value [3]. Additional advantages include reduction in most harmful exhaust emissions, improved biodegradability, inherent lubricity, higher flash point and domestic source.

The plants of cucurbitaceae family of which pumpkin (*C. maxima*) is a member, are generally grown in the tropical, subtropical, arid and temperate climates of the world (especially in northern Nigeria) commonly known in Hausa as *Kabewa* [7]. Pumpkins are planted in the months of April to June. The plant covers the soil surface within 4 – 6 weeks and yields up to 600 kg/m^2 [8]. The oil content from the research is promising because according to Food and Agricultural Organization (FAO), any seed containing greater than 17% of oil is considered to be an oil seed and can be utilsed as feedstock for biodiesel production [1].

Recently, environmentalists have started to debate on the negative impact of biodiesel production from edible oil due to large-scale production of biodiesel from edible oils which may bring global in balance to the food supply and market demand [9]. Therefore this paper studied production of biodiesel from *Cucurbita maxima* seed oil in an attempt to harness its potential as a feedstock.

This study discovers the potential of *Cucurbita maxima* seed oil in biodiesel production especially in terms of oil content, methyl esters profile of the biodiesel produced and fuel properties. This study will help the researcher to uncover the modification of biodiesel production in terms of biodiesel reactor where a common household blender was used as a reactor that many researchers were not able to explore.

MATERIALS AND METHODS

Sample collection and preparation

Sample was collected from ripped seeds of pumpkin (*C. Maxima*) in Kawo Area within Kaduna metropolis, Nigeria.

The leaves and seeds were identified in the Herbarium section of Biological Sciences Department, Ahmadu Bello University Zaria, with a voucher number 2238 and was kept for future reference. The seeds were peeled to obtain the kernels, which was air dried and pulverized to a fine powdered form and stored in an air tight plastic container.

Extraction procedure

About two hundred gram (200 g) of air dried and pulverized plant seeds of *Curcubita maxima* was weighed out and packed into a thimble, which was in turn placed into a Soxhlet extractor. Extracting solvent (normal hexane (500 cm^3)) and anti-bumping chips were placed into a 1000 cm^3 round bottom flask and heated on heating mantle at 60 ◦C. The extraction was allowed to continue until the solvent was clear. The solvent in the round bottomed flask was collected and concentrated in vacuo using a rotary evaporator at 40 ˚C. The process was repeated to obtain the mean of the percentage extraction and enough oil for further analysis.

$$\% \text{ Extraction} = \frac{\text{Weight of oil extracted}}{\text{We of sampleight}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots \qquad \textbf{(1)}$$

Pre-treatment of the Oil (Acid Degumming)

About two hundred (200 gram) of *Cucurbita maxima* oil was weighed and heated to 70 ˚C on a heating mantle. About 25 % citric acid was prepared by dissolving 250 g citric acid in 1000 cm^3 of distil water and was added in the ratio of 3:1 citric acid to oil then mixed for 5 min. This was centrifuged for 30 min for separation of gums and other impurities which settled at the bottom. Oil at the top of the centrifuge test tubes, was decanted and reheated [10].

PHYSICOCHEMICAL PROPERTIES OF THE SEED OIL

Determination of the saponification value

The American Standard for Testing and Material (ASTM) method- (D 5558-95) [11] was used for the determination of the saponification values of the vegetable oil. The oil (5 g) was weighed into Erlenmeyer flask and 0.5M ethanolic KOH was prepared by dissolving 7 g of KOH in

250 cm^3 ethanol and 25 cm^3 of the prepared 0.5M ethanolic KOH was added and the resulting mixture was refluxed for 60 minutes. The resulting solution was subsequently titrated against 0.5M HCl prepared by diluting 10.7cm^3 HCl in 250 cm^3 of distil water using phenolphthalein as indicator. The resulting end point was obtained when the pink colour changed into colourless. The same procedure was used for the blank. The saponification value (SV) was then calculated using the expression;

$$\mathrm{S.V} = \frac{5.61\ (\mathrm{B-S})\times \mathrm{M\ \ of\ HCl}}{\mathrm{We3ight\ of\ sample}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(2)}$$

Where;

B – Vol. of HCl required by blank

S – Vol. of HCl required by sample

M – Molarity of HCl

5.61– Molar mass of KOH

Determination of acid value

Acid value of the oil was determined by ASTM method (ASTM – D 974(00) [11]. The oil (0.5 g) of the oil was weighed into 250 cm^3 conical flask and 50 ml of neutralized ethyl alcohol was added, prepared by neutralizing a solvent mixture of 25 cm^3 ethanol and 25 cm^3 diethyl ether with 0.1M ethanolic KOH prepared by dissolving 1.4 g KOH in 250 cm^3 of ethanol using phenolphthalein as indicator. The mixture was added to the oil and heated on a water bath to dissolve the oil. The solution was then titrated against 0.1M KOH prepared by dissolving 1.4 g of KOH in 250 cm^3 of distill water using phenolphthalein as indicator. The acid value was determined after which the free fatty acid was calculated respectively as follows;

$$\text{Acid Value} = \frac{\mathrm{A} \times \mathrm{M} \times 56.10}{\mathrm{W}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \qquad \mathbf{(3)}$$

Where,
A = ml of 0.1M KOH consumed by sample
M = Molarity of KOH
W = weight in grams of the sample
Then,

$$\text{Free fatty acid} = \frac{\text{Acid value}}{2} \quad \ldots\ldots\ldots\ldots\ldots \qquad \mathbf{(4)}$$

Determination of iodine value

The oil (0.5 g) was weighed into conical flask and 20 cm^3 of carbon tetrachloride was added to dissolve the oil. 25 cm^3 of Wijs reagent was added into the flask using a measuring cylinder in a fume chamber and a stopper was inserted.The content of the flask was vigorously swirled and kept in the dark for 35 minutes. Exactly 20 cm^3 of 10% aqueous potassium iodide prepared by diluting 10 cm^3 of potassium iodide in 90 cm^3 of distill water was added into the content of the flask using a measuring cylinder. The content was titrated with 0.1M sodium thiosulphate solution prepared by dissolving 3.95g of anhydrous $Na_2S_2O_3$ in 250 cm^3 of distill water. Few drops of 1% starch indicator were added and the titration continued by adding the sodium thiosulphate drop wise until coloration disappeared after vigorously shaking. The same procedure was used for the blank test. The Iodine Value (I.V) was given by the expression; [11]

$$\text{Iodine value} = \frac{126.9\,C(V_1 - V_2)}{M} \ldots\ldots\ldots\ldots\ldots \quad \mathbf{(5)}$$

Where,

C = concentration of sodium thiosulphate

V_1 = volume of sodium thiosulphate used for blank

V_2 = volume of sodium thiosulphate used

M = mass of sample

12.69= Constant.

Determination of refractive index

Abbey refractometer was used in this determination. A drop of the sample was transferred into a glass slide of the refractometer. Water at 30 °C was circulated round the glass slide to keep its temperature uniform. Through the eye piece of the refractometer, the dark portion viewed was adjusted to be in line with the intersection of the cross. At no parallax error, the pointer on the scale pointed to the refractive index. This was repeated and the mean value noted and recorded as the refractive index.

PRODUCTION OF BIODIESEL

Transesterification

A modified method of biodiesel reaction was employed in terms of timing, catalyst, temperature, methanol to oil ratio and a biodiesel reactor, which differs from the convectional biodiesel production. The 100 g of the pretreated oil was heated to 60 ◦C and transferred into the jurk of a master chep household blender.About 20 g methanol containing potassium hydroxide 1 % w/w (1g) of oil to form potassium methoxide was added. The stirring speed was kept constant at 10000 rpm using a time interval of 2, 4 and 6 min to avoid over heating the blender. About 16 g potassium methoxide solution was initially added representing 80 % and stirred for 4 min and the remaining 4 g was added at the 4th min representing 20% to complete the6th min, because the reaction was very slow at the beginning due to mixing and dispersion of alcohol into the feedstock[12-14].

DETERMINATION OF FUEL PROPERTIES OF BIODIESEL

Determination of Pour Point

The oil sample (150 cm^3) was poured into the test jar to the level mark. The test jar was closed with the cork carrying the high – pour thermometer. The position of the cork and the thermometer were adjusted for the cork to fit tightly, the thermometer and the jar were coaxial and the thermometer bulb was immersed 3mm below the surface of the sample. After this, the test jar was placed into the cooling medium. The sample was cooled at a specified rate and examined at interval of 3 ^{o}C for flow characteristics until a point was reached at which the sample showed no movement when the test jar was held in a horizontal position for 5seconds. The observed reading of the thermometer was recorded. Exactly 3^{o}C was added to the recorded temperature and the result was recorded as the pour point.

Determination of kinematic viscosity

The temperature of the viscometer bath was adjusted to 38.9 ^{o}C. A calibrated thermometer was held in upright position and inserted into the bath by a holder. A clean dry calibrated viscometer was selected and carefully flushed with a dry nitrogen gas to remove the moist room air. A sample of the biodiesel was drawn up into the working capillary of the viscometer and the timing bulb was then allowed to drain back as an additional safeguard against moisture condensing or freezing on the walls. The charged viscometer was inserted into the bath at a depth such that at no time during the measurement of the flow time was any portion of the sample in the viscometer less than 20 mm below the surface of the bath. The viscometer together with its content was allowed to remain in the bath for 30 minutes to reach the test temperature (38.9 ^{o}C). A suction bulb was used to adjust the head level of the biodiesel to a position in the capillary arm of the viscometer about 7 mm above the first timing mark. The biodiesel was then allowed to freely flow and the time required for the meniscus to pass from the first to the second timing marks was noted with a stop watch. The procedure was repeated to make a second measurement of flow time and the average of these determinations was used to calculate the kinematic viscosity. The viscometer was thoroughly cleaned with sample solvent and dried by vacuum. The procedure was repeated for the other samples of the biodiesel (ASTM D 445-97) [11].

Calculation:

$$V = C \times t \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad \textbf{(6)}$$

Where,

v = kinematic viscosity, mm^2/s

C = calibration constant of the viscosity, (mm^2/s)

t = mean flow time

Determination of cloud point

The cloud point was determined using ASTM D2500 [11]. A cylindrical test tube was filled with the biodiesel to a specific level (5 cm^3) and clamped with a wooden clamp bearing thermometer. The test tube was placed on the ice/salt bathe and the set up inspected at intervals for cloud formation. The temperature at which a distinct cloudiness appeared at the bottom of the test tube was observed and recorded as the cloud point of the biodiesel.

Determination of flash point

The flash point was determined using ASTM D93 [11]. Seta MultiflashPensky-Martens Flash Point Module Part Number 34100-2 was used to determine the flash point. The automatic PMCC module conforms precisely to national and international Pensky-Martens Closed Cup flash point test methods. It comprises a heated cup and lid, and a DIPS pod containing the dipping mechanism, gas and electric ignitors, fire detection system and a stirrer. The Pensky- Martens module was used with the Multiflash Universal Base unit (p/n 34000-0). The base unit recognises the Pensky-Martens module was connected and instantaneously sets up standard test parameters and calibration data

Determination of cetane number

The cetane number was determined based on the formula proposed by Demirbas[15]. The formula was given

$$CN = \frac{46.6 + 5458}{S.V - 0.225 \times I.V} \quad \ldots\ldots\ldots\ldots\ldots \quad \textbf{(7)}$$

Where,

S.V = Saponification of the biodiesel

I.V = Iodine value of biodiesel

Determination of specific gravity

Specific gravity bottle was washed, rinsed with acetone and dried at room temperature in a dessicator and the weight of the empty bottle determined using an electronic weighing balance. The weight of the bottle filled with water was recorded. The same procedure was repeated with the oil and the specific gravity computed as follows;

$$\text{Specific gravity} = \frac{W_2 - W_1}{W_3 - W_1} \quad \ldots\ldots\ldots\ldots \quad \textbf{(8)}$$

where,

W1 = weight of empty bottle

W2 = eight of bottle + oil

W3 = weight of bottle + water

Determination of Colour

The visual determination of the colour of the biodiesel was done using ASTM D – 1500 (98) [11]. The readings of the colour were made with Lovibond Tintometer. Prior to this, a sample container filled to a depth of 50mm with distilled water was placed in the compartment of the colorimeter with the standard glasses to facilitate color adjustment. The biodiesel sample was then placed in its container in the middle of the compartment. The containers were covered to exclude all exterior light. The light source was switched on and the colour of the sample compared with the standard glasses ranging from 0.5 to 4.5. When an exact colour match was not found and the sample colour was between two standard colours, the higher of the two colours was reported.

Determination of FTIR of the produced biodiesel

The possible functional groups in the produced biodiesel was determined using Fourier Transform Infrared (FTIR) spectrometer (model: Cary 630 Agilent Technology), at the National Research Institute for Chemical Technology (NARICT), research laboratory, Zaria, Kaduna State. Exactly 0.5 ml was applied on the sodium chloride cell to obtain a thin layer. The cell was mounted on the FTIR and scanned through the IR region.

Determination of Pumpkin Oil Methyl Esters (POMEs)

The fatty acid composition of the POMEs was analyzed using Gas Chromatography-Mass Spectrophotometer, at the National Research Institute for Chemical Technology (NARICT), research laboratory, Zaria, Kaduna. The Biodiesel produced was analyzed using GCMs model QP2010 plus Shimadzu equipped with detector and slit injection system the initial temperature was maintained at 60^{o}C for 3 minutes and was gradually increased to 250 ^{o}C. 1.6ul of solution was injected for analysis and the sample injection temperature was maintained at 250^{o}C throughout the experimental period the carrier gas Helium flow, was 2 ml per minute.

Statistical Analysis

Statistical analysis was performed with SPSS for windows 7.0 software. Descriptive statistical analysis gave the mean and standard deviation of the parameters properties of the crude oil extracted and fuel properties of the biodiesel produced.

RESULTS AND DISCUSSION

The results of physicochemical properties of the crude oil and the fuel properties of the biodiesel produced from the oil are presented as Mean ± SD in Tables 1 and 2 respectively. The infrared spectrum of the biodiesel produced is presented as figure 1.

Table. 1: Result of physicochemical properties of the seed oil (Mean ± SD)

Oil property	**Unit**	***C. maxima* (Pumpkin)**
Oil Content	Percent	42.13± 0.1%
Saponification Value	mgKOH/g	210.38± 0.1
Iodine Value	gI2/100g	182.74± 0.4

Peroxide value	Meq/kg	2.5± 0.6
Acid value	mgKOH/g	8.415± 0.8
Relative density	Dimensionless	0.883± 0.00
Refractive index	Dimensionless	1.463± 0.0
Free fatty acid	Percent	4.207± 0.4
Unsaponifiable value	mgKOH/g	3.20± 0.0
Gums	%	7.6 ± 0.1 %

Table .2: GC-MS result for biodiesel produced from *Cucurbita maxima* seed oil

FATTY ACID	**CARBON NUMBER**	**MOLECULAR FORMULAR**	**% COMPOSITION**
Myristic Acid	14:0	$C_{15}H_{30}O_2$	0.85
Nonenoic Acid	9:0	$C_{10}H_{18}O_2$	0.66
Palmitic Acid	16:0	$C_{17}H_{34}O_2$	17.64
Linoleic Acid	18:2	$C_{19}H_{34}O_2$	17.73
Capric Acid	10:0	$C_{11}H_{22}O_2$	0.85
Oleic Acid	18:1	$C_{18}H_{34}O_2$	33.18
Stearic Acid	18:0	$C_{19}H_{38}O_2$	13.28
Arachidic Acid	20:0	$C_{21}H_{42}O_2$	3.40
Behenic Acid	22:0	$C_{23}H_{46}O_2$	1.78
Non-methyl esters	--------------	-----------	10.63
Total	---------------	------------	100

Table.3: Fuel properties of POMEs (Mean ± SD)

Fuel parameter	**POMEs**	**ASTM Limits** [4]	**European Standard** [4]
(%)Yield of Biodiesel	96.78 ± 0.9	-	-
Colour	2.1 ± 0.0	3.5	-
Specific gravity g/cm^3	0.8713 ± 0.0	-	-
Kinematic viscosity (mm^2/s)	4.94 ± 0.0	6.0 Max	3.5-5.0
Pour point (^{o}C)	-0.3 ± 0.0	NS	NS
Cloud Point (^{o}C)	1.1 ± 0.0	NS	NS
Flash point (^{o}C)	127 ± 0.0	130 min	<120
Sulphur content (ppm)	0.03 2 ± 0.01	0.050	-
Cetane number	54.148 ±0.52	Min47	-

NS= Not specified; POME = Pumpkin Oil Methyl Ester

Physicochemical properties

The result of physicochemical properties of *Cucurbita maxima* seed oil studied was presented in Table 1. The percentage oil content of *Cucurbita maxima* was 42.13 ± 0.11%. The oil content in this study was lower than the oil content of *C. maxima* (55.8 %) and *C. pepo* (52.8%) reported by Bwade *et al* [16]. which may be likely due to difference in solvent use in the oil extraction. According to Food and Agricultural Organization (FAO) as reported by Akinoso and Raji [17], any seed containing greater than 17% of oil was considered to be an oil seed and can be utilised as feedstock for biodiesel production. As such *Cucurbita maxima* seed was good feedstock for biodiesel. The relative density of the *C. maxima* oil was 0.883 ± 0.0, which was lower than the relative density of *Telfairia occidentalis* seed oil (0.911) investigated by Nwabanne [18], and *Anarcadium occidentals* seed oil (0.910) investigated by Aremu and Akinwuni [19]. The lower relative density observed in the *C. maxima* seed oil will have less effect on the viscosity of the seed oil resulting in good atomization of the biodiesel produced from the seed oil in the engine performance. Since the relative density of seed/vegetable oils are dependent on fatty acid composition, minor components and temperature as reported by Fakhri and Qadir [20].

The refractive index of the oil is 1.463 ± 0.0. This value is lower than that of beniseed oil (1.474) as investigated by Aremu *et al* [21]. The refractive index of an oil is the ratio of speed of light at a defined wavelength to its speed in the oil/fat itself according to Mabaleha *et al* [22]. The difference in the refractive index of the *C. maxima* oil compared with similar seed oils reported in literature was due to the variation in wavelength and temperature, degree of unsaturation and substitutions of component fatty acids.

The acid value of *Cucurbita maxima* was 8.415 ± 0.8 mgKOH/g. The lower the acid value, the lower the free fatty acid, the more suitable, the oil for transesterification process. The acid value of the oil was higher in comparison to the acid value of Agusi seed oil with 4.0 mgKOH/g reported by Mabaleha *et al* [22] and rubber seed oil 8.17 mgKOH/g reported by Eka *et al* [23], which indicated that the oil will be unstable over a long period of time and will not be protected against rancidity and peroxidation. This could be attributed to lack of natural antioxidants in the seeds such as vitamins C and A, as well as other possible phytochemicals like flavonoids [22].

The saponification value for *Cucurbita maxima* was 207.57 ± 0.1 mgKOH/g, which is lower when compared with *cocos nucifera* oil (246 mgKOH/g) investigated by Eka *et al* [23]. However biodiesel derived from oil with high saponification value causes exhaust emissions during burning in the engine [16].

The iodine value of *Cucurbita maxima* was 182.74 ± 0.4 gI_2/100g, which was higher than the iodine value of refined (87.72 gI_2/100g) and unrefined castor oil (84.8 gI_2/100g) as investigated by Aremu *et al* [21]. This indicated that the oil studied was suitable for biodiesel production since low iodine value of vegetable oil produces biodiesel with high cloud and pour points; higher cloud and pour points means poor engine performance in cold temperatures [23].

The viscosity for *Cucurbita maxima* was 25.0 ± 0.0 mm^2/sec, which was lower compared to the viscosity of *Cucurbita pepo* oil (93.65 mm^2/sec) according to Bwade *et al.* [16] and *black* *benised* seed oil (33.2 mm^2/sec) as investigated by Furiku *et a l* [24]. According to Aremu and Akinwuni [19], viscosity increases with molecular weight which in turn will affect injection lubrication, increase engine deposits and fuel atomization [25].

The peroxide value of *Cucurbita maxima* was 2.5 ± 0.06Meq/kg which is lower to Melon seed oil 5.63 Meq/kg as investigated by Oloefe *et al* [26] and higher than groundnut seed oil 0.74 Meq/kg [27]. This showed that the oil will have high level of deterioration when attacked or exposed to oxygen, since peroxide value indicated the level at which deterioration will take place as a result of oxidation owing to the availability of oxygen during storage [29].

The unsaponifiable value for *Cucurbita maxima* was3.20 ± 0.4 mgKOH/g, which is higher compared to African pear seed oil (2.62 mgKOH/g) and Soy bean seed oil (0.837 mgKOH/g) as reported by Aremu *et al* [21]. The high level of the unsaponifiable matter in the oils indicated the presence of good lubricating properties [21].

The percentage degumming after centrifugation revealed that *Cucurbita maxima* is having 7.6 ± 0.1 %. This was above the percentage degumming of crude Canola oil 4.50 ± 0.0% and crude Sunflower oil 3.20 ± 0.0 % as investigated by Nick and Greg [10]. This indicated that there was high level removal of hydratable and non-hydratable phosphatides, and other impurities especially metals contamination (P and Ca specifically) and also improvement in the yield of biodiesel production [24].

Fatty acid methyl esters

The profile of fatty acid methyl esters in POMEs shown in Table 2 indicated oleic acid ester as the dominant ester with one level of unsaturation. Oleic acid ester was dominant in Jatropha, mahua, neem, soap nut and karaja seeds oil as reported by Khandelwal and Chauhan [30]. However, linoleic acid ester with two level of unsaturation was the dominant methyl esters in soybean, sunflower, rape and grape seeds oil [32]. Biodiesel produced from this feedstock could deteriorate on long storage due to its susceptibility to oxidation, since the higher the level of unsaturation the more the instability of the biodiesel produced [10]. Conversely, the presence of palmitic, myristic, stearic, and archidic acids as methyl esters in the biodiesel will help to enhancing the stability of the biodiesel, been saturated compounds and less susceptibility to peroxidation [33]. It was also observed that POMEs have less long chain of the acid methyl esters which in turn will have less effect on the fuel properties of the biodiesel produced [32].

Fuel properties

The fuel property of the biodiesel produced from pumpkin oil (POME) is shown in Table 3. The percentage biodiesel yield was recorded to be 96.78± 0.9%., which was higher than the percentage yield of biodiesel produced from the oil seeds of *Gul Mohr* (87%) as investigated by Edward and Peggy [26] and *Lagenaria vulgaris* with 96.52% as reported by Sokoto *et al* [32].

The kinematic viscosity of the fatty acid methyl esters corresponded to biodiesel specification for both ASTM and European Standard limits, which indicated the presence of short chain unsaturated methyl fatty acid esters and was likely to produce less deposit when burnt in combustion engines [32].

The flash point of the POME conformed to the ASTM and EN [5] for biodiesel limit. This showed that the biodiesel produced has fewer tendencies to ignite accidentally, since flashpoint is the lowest fuel temperature at which application of ignition source causes the vapor of the fuel sample to ignite under the prescribed test conditions and also a parameter used to assess the overall flammability hazard of fuel [22].

The cetane number of the POME corresponds to the biodiesel specification for ASTM standard limits. The higher the cetane number the better it was in its ignition properties. Biodiesel has higher cetane number than conventional diesel fuel, which results in higher combustion efficiency [34].

The pour point of the POME was -0.4± 0.0^{o}C. There was no standard specification for pour point due to variation in atmospheric condition.

The cloud point of the POMEs was 1.1± 0.0 ^{o}C. Cloud point test characterized the low temperature operability of diesel fuel. There was no standard specification for cloud point due to variation in atmospheric condition.

The specific gravity of the POME was 0.8713± 0.0 g/cm^3 this is lower than the specific gravity of biodiesel produced from *Lagenaria vulgaris* with specific gravity of 0.8879g/cm^{3}as reported by Sokoto *et al* [32]. This indicated that the biodiesel produced can be handled and stored safely. It was an important physical property in handling and storing of fuels [29].

IR spectra

The IR spectra of Pumpkin Oil Methyl Esters primarily composed of mono-alkyl ester of fatty acids were shown in Fig.1. This is confirmed by the presence of an intense band of C=O stretching of methyl ester and O-CH_3 group in the spectra. The absorption band attributed to O-CH_3 group confirmed that the transesterification process has taken place [35]. The FTIR profile of the biodiesel shows several major absorption bands at 1738 cm^{-1}, 1176 cm^{-1}, 2938 cm^{-1} and 1446 cm^{-1} which agreed with the findings by Sanford *et a l* [36]. This was also confirmed by the absorption spectra having strong ester peaks at 1750 cm^{-1} (C=O vibration) and around 1170 – 1200 cm^{-1}(C-O vibrations) and similar transmittance pattern within the range 4000 cm^{-1} to 500 $cm^{-1}$of the biodiesels produced as reported in literature [35].

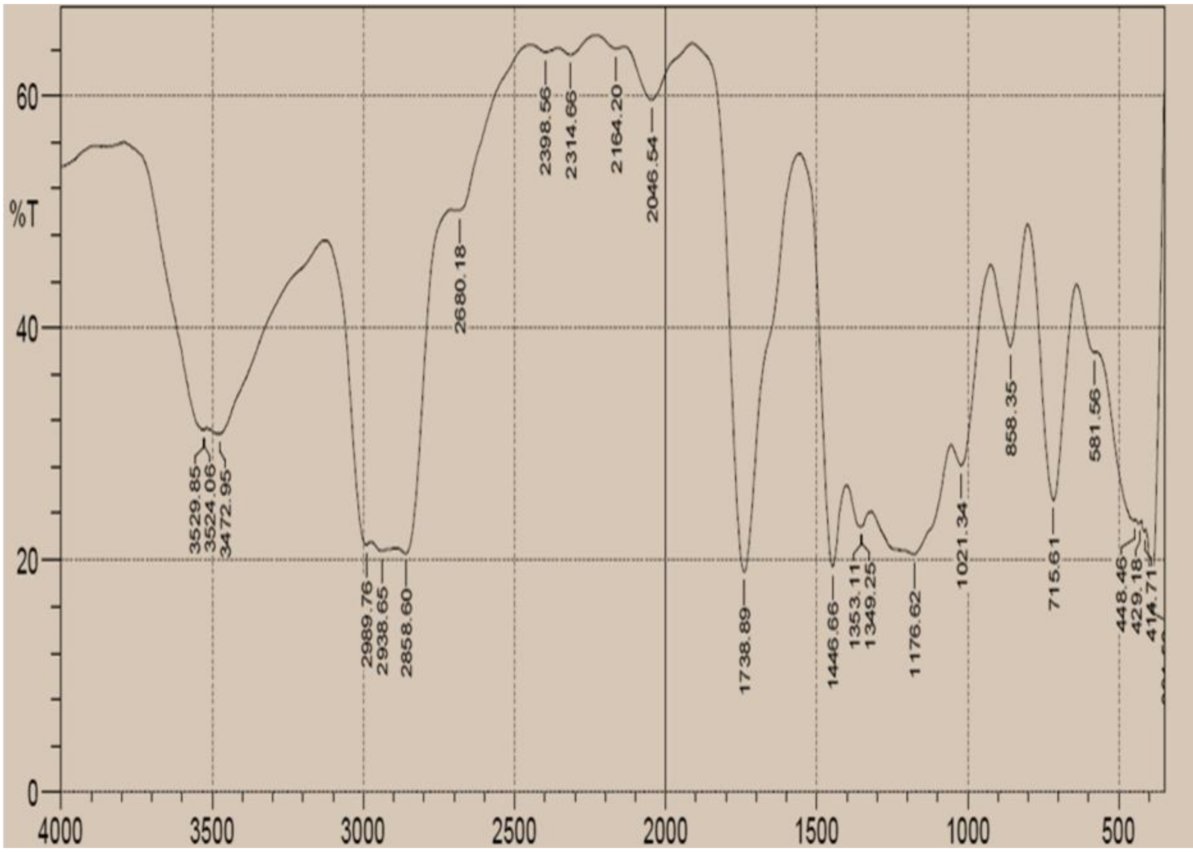

Figure 1: Infrared Spectra of the Biodiesel produced from the *C. maxima* (POME)

POME = Pumpkin Oil Methyl Ester

CONCLUSION

The oil contents of the plants seed showed viability of feedstock for biodiesel production and the physicochemical properties of the oils are promising with the exception of saponification and free fatty acid values which were above their limits for biodiesel production. The percentage of biodiesel production from the oil was high and has less long chain methyl esters. The FTIR showed the intense band of C=O stretching of methyl ester and O-CH_3 group for the biodiesel produced and the fuel properties agree with the ASTM and EN Standard limits.

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