Production and Biodegradability of Biodiesel from *Citrullus Lanatus* Seed Oil

Hadiza Abubakar[1], Aliyu Jauro[2], Mahmood I.Abubakar[3], Abbas Abubakar[4], Salim Yushau[5], Sha'aban Sallau[6], Hamza Yakubu[7]

[1,2,4,5,7]*Department of Chemistry, Abubakar tafawa Balewa university Bauchi, Bauchi State, Nigeria*
[3-]*Department of Pure and Applied Chemistry, Usmanu Dan fodio university Sokoto, Sokoto State, Nigeria*
[6-] *Department of Pure and Applied Chemistry, Bayero University Kano, Kano State, Nigeria*

***Abstract:-* Biodiesel is becoming popular as an environmentally friendly fuel, it has been used as an alternative for diesel fuel in the automotive industry, commonly known as No. 2 diesel. This research seeks to explore the potentials of *Citrullus lanatus* (Watermelon) seed oil as feedstock for biodiesel production. Various samples were collected, extracted, analyzed, trans-esterified and Characterized using standard spectroscopic and analytical procedures. The quality of the biodiesel and its biodegradability was also investigated. The oil quality parameters of *Citrullus lanatus* were found to be: oil content of 43.67 %, acid value 10.61 mgKOH/g, Iodine value 40.91 gI_2/100g, Moisture content 2.83 %, saponification value 137.45 mgKOH/g, Peroxide value 8.00 meq/kg. The biodiesel yield, specific gravity (SG), density and flash point of the methyl ester were found to be 81 %, 0.804 , 0.87 g/cm^3 and 124 ^{o}C respectively. The biodiesel was found to be inherently degradable (38.45 %). These results showed that *Citrullus lanatus* seed oil has a potential to be used as a source of biodiesel, which may be considered as more economic and environmentally friendly.**

***Key words:- Citrullus lanatus*, biodiesel, biodegradability, cetane number**

I. INTRODUCTION

Biodiesel is a clean and renewable fuel which is considered to be the best substitution for diesel fuel (Bulent *et al.*, 2014). The advantage of this biofuel over the conventional diesel fuel includes: high cetane numbers, low smoke and particulates, low carbon dioxide and hydrocarbon emissions; it is biodegradable and non toxic. It has low carbon monoxide (CO), unburned hydrocarbons (HC) and smoke emissions (Kumar and Kant, 2013).

The limited (and fast diminishing) resources of fossil fuel, increasing price of crude oil, and environmental concern have been the diverse reasons for exploring the use of vegetable oil as an alternative fuel. However, the direct use of vegetable oil has not been satisfactory, because of its viscous nature and poor ignition property. However, methyl/ethyl esters of fatty acid produced from such oils have proved promising alternative now called biodiesel (Jauro and Haruna, 2011).

The transportation of petroleum across the world is now frequent. Consequently the potential for oil spill which constitutes a major source of ecosystem contamination is enormous (Jauro and Haruna, 2011). Therefore, as biodiesels are becoming commercialized, their fate in the environment is also an area of concern. Among these concerns, water quality and soil fertility are the most important issues for the ecosystem (Zhang *et al.*, 1998). Therefore, it is imperative to examine the biodegradability of biodiesel fuel and their biodegradation rate in natural environment so as to have an idea of how persistent they would be when discharged into the environment (Peterson and Gregory 1997).

This paper is aimed at extracting the oil of *Citrullus lanatus*, converting the oil to biodiesel and evaluating the fuel quality and biodegradability of the biodiesel.

1.1 Citrullus lanatus

Citrullus lanatus (Watermelon) belongs to the Cucurbitaceous family. *Citrullus lanatus* is known as watermelon because of its large amount of water content, which is about 93% by weight (Erhirhie, 2013). Water melon fruits give chilling effect and reduce thirst. The plant is traditionally use for centuries in the treatment of various diseases. It is an important medicinal plant used in the Ayurveda and traditional system of medicine (Gill *et al.*, 2011). The plant is rich in flavanoids, alkaloids, saponins, glycoside, tannins and phenols. It has nutritive values and is good for human health. It grows in India, Africa, Asia, USA, China, Russia, Romania and Bulgaria etc.

The advantages that encourage the use of vegetable oils include their relatively low viscosity-temperature variation; that is their high viscosity indices, which are about twice those of mineral oils (Honary, 2004). Additionally, they have low volatilities as manifested by their high flash points (Emmanuel *et al.*, 2009, Honary, 2004) Significantly, they are environmentally friendly: renewable, non-toxic and biodegradable (Howell, 2007).

In summary, engine lubricants formulated from vegetable oils have the following advantages deriving from the base stock chemistry:

i. Higher Lubricity resulting in lower friction losses, and hence more power and better fuel economy.
ii. Lower volatility resulting in decreased exhaust emissions.
iii. Higher viscosity indices.
iv. Higher shear stability.

v. Higher detergency eliminating the need for detergent additives.
vi. Higher dispersancy.
vii. Rapid biodegradation and hence decreased environmental / toxicological hazards (Erhan and Perez,2002)

Where: W_i = initial weight of sample (before drying), W_f = final weight of sample (after drying)

II. MATERIALS AND EQUIPMENT/ INSTRUMENTS

Mortar & pestle were provided then Citrullus lanatus, soxhlet extractor set-up, rotary shaker(Bio Techno Lab Mumbai India)and retort stand were used, water bath HHW420(B scientific England), heating mantle, beaker, and Reflux condenser were also provided ,Heating mantle (China 98-1-B, Lab instrument),Oven (BS062455),Weighing balance (Model: 6354. Capacity: 200 gm.),Hot plate (Model US150), pH meter (Model # 151-R) were also provided.

2.1 Reagents and Solvents

The reagents used were of Analytical grade from BDH Chemicals Limited and Sigma-Aldrich Gmbh, Germany.

2.2 Seed Collection and Preparation

Citrullus lanatus seed was purchased from Muda Lawal market, Bauchi metropolis, Bauchi State, Nigeria and was identified at the Botany Unit, Department of Biological Sciences, Abubakar Tafawa Balewa University, Bauchi. The sample was washed, air-dried, pulverized using a mortar and pestle, and stored in an air tight container for subsequent experiments.

*2.3 Preparation of Reag*ents

The (A.O.A.C, 1975) standard method for the preparation of reagents was used in this research.

2.4 Methods

2.4.1 Moisture Content Determination

Citrullus lanatus 1.00 g seed was placed in a dried pre-weighed crucible. It was then placed in an oven set at temperature of 105°C and allowed to dry for an hour. The crucible was then removed and allowed to cool in a desiccator before reweighing. The process was repeated until a constant weight was attained. The moisture content was determined using the formula bellow:

$$\text{Percentage moisture} = \frac{W_i - W_f}{W_i}$$

2.4.2 Oil Extraction

The method adopted by Abubakar *et al.*(2020) Mahmoud *et al*. (2019) and Jauro and Haruna, (2011) with slight modification. The oil was extracted from the pulverized seeds (530.00 g) in a soxhlet extractor using n-hexane as the solvent for 8 hours until it was certified that at least 90% of the oil was extracted. The oil was filtered to remove impurities and the solvent was recovered by the use of rotary evaporator. The recovered oil was further evaporated in an oven at a temperature of 105°C, the moisture and traces of solvent were removed. The oil quality parameters such as acid value, iodine value, peroxide value, specific gravity, moisture content, oil yield, color, kinematics viscosity were determined based on AOAC (1975) methods.

$$\%\ \text{crude oil yield} = \frac{\text{weight of the extracted oil}}{\text{Weight of the sample}}$$

2.5 Physical Analysis Of The Oil

2.5.1 Specific Gravity

An improvised specific gravity bottle was washed, rinsed with acetone and dried in an oven. The bottle was cooled at room temperature in a desiccator and the weight of the empty bottle was determined. The weight of the bottle filled with water was recorded. Then the water was poured out and rinsed with acetone and dried in the oven. The same procedure was repeated with the seed oil sample and the specific gravity computed as follows (Knothe, 2005).

$$S.G = \frac{W1 - W2}{W3 - W2}$$

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

2.5.2 Density

An improvised specific gravity bottle was washed, rinsed with acetone and dried in an oven. The bottle was cooled at room temperature in a desiccator and the weight of the empty bottle was determined on weighing balance. The weight of the bottle filled with the sample was recorded. The volume of the oil in the bottle was also recorded and the density was computed as follows (Knothe, 2005).

$$Density = \frac{(wt\ of\ bottle + oil) - wt\ of empt\ bottle}{vol. of\ oil}$$

2.6 Chemical Analysis of the Oil

2.6.1 Free Fatty Acid (FFA)

The method adopted was that described by Abubakar *et al.* (2020). A *Citrullus lanatus* oil (1.00 g) was measured into a 250 ml conical flask and warmed. Methanol (10.00 ml) was added and accompanied by thorough stirring, followed by the addition of 2 drops of phenolphthalein indicator and a drop of 0.2 M NaOH solution. The contents were then titrated with 0.2 M NaOH until a light pink color which persisted for 1 minute was seen. The end point was recorded and used in calculating the FFA as follows:

$$F.F.A = \frac{Titrevalue\ \text{x}M\text{x}28.2}{vWeight\ of\ sample}$$

Where; M = Molarity of the base

2.7.1 Acid Value (A.V)

2.7.1.1 Principle:

The acid value was determined by direct titration of the oil/fat in an alcoholic medium against standard potassium hydroxide/sodium hydroxide solution.

2.7.1.2 Procedure:

A 5.00 ml of diethyl ether and 5.00 ml of ethanol were mixed in a 250 ml beaker. The resulting mixture was added to 2.0 g of oil in a 250 ml conical flask and few drops of phenolphthalein were added to the mixture. The mixture was titrated with 0.1M NaOH to the end point with consistent shaking for which a dark pink colour was observed and the volume of 0.1M NaOH (V_o) was noted.

2.7.2 Peroxide Value (P.V)

The method adopted was that described by Abubakar *et al.* (2020). A *Citrullus lanatus* seeds oil (1.00 g) was measured in to a 250 ml conical flask and 30.00 ml of glacial acetic acid/chloroform (3:2 V/V) was added. The contents were shaken until they dissolved. Saturated potassium iodide (1.00 ml) was added followed by the addition of 0.5 ml starch indicator. This was titrated with 0.2 N $Na_2S_2O_3$ until the dark blue color just disappeared. Blank determination was also carried out and the peroxide value calculated as follows:

$$P.V = \frac{S - B \text{ x}1000\text{xN}}{W}$$

Where, S= titre volume of sample, B= titre volume of blank, N= normality of sodium thiosulphate solution, W= weight of oil sample

2.7.3 Saponification Value (S.V)

The method adopted was that described by Abubakar *et al.* (2020). *Citrullus lanatus* oil (2.00 g) was measured in to a 250 ml conical flask and 25.00 ml of 0.5 M ethanol potassium ethoxide solution was added. A reflux condenser was attached and the flask content refluxed for 30 minutes on a heat source while swirling until it simmered. The mixture was then titrated against 0.5 M HCl using phenolphthalein indicator while still hot. A blank determination was also carried out under the same conditions and the saponification value was calculated as follows:

$$S.V = \frac{B - S \text{ x}28.05}{W}$$

Where; B = titre value of blank, S = titre value of sample, W = weight of oil

2.7.4 Iodine Value

The method adopted was that described by Abubakar *et al.*(2020). *Citrullus lanatus* seed oil (1.00 g) was measured in to a 250 ml conical flask followed by 5.00 ml of Hanus solution and the flask stoppered. The contents were mixed and kept in a dark drawer for 30mins. It was then titrated with 0.2 N $Na_2S_2O_3$ until the solution became light yellow. Two (2) drops of 1 % starch indicator was added and the titration continued until the blue color just disappeared. A blank determination was also carried out under the same conditions and the I.V calculated as follows:

$$I.V = \frac{B - S \text{ x}12.69\text{x}N}{W}$$

Where; B = blank, S = sample titre, N = normality of $Na_2S_2O_3$

2.7.5 Kinematic Viscosity

An improvised method was used for the determination of this parameter. The *Citrullus lanatus* seed oil was filled in to a clamped burette and was allowed to run freely in to a beaker. The time of the flow was recorded and the kinematic viscosity was calculated as follows (Marshal *et al.,* 1995):

$$K.M = \frac{vol. of\ oil\ collected}{Time}$$

2.7.6 Static Viscosity

The adopted was that described by (Marshal *et al.,* 1995). The static viscosity was determined by calculation using the following formulae

$$St.Vics = \frac{Kinematic\ viscosity}{density}$$

2.7.7 Pour Point (P.P)

An improvised method was used for the determination of this parameter (Ugah *et al.,* 2007). The cylindrical test tube was filled with the *Citrullus lanatus* seed oil to a specific level (10.00 ml) and clamped with wooden clamp bearing a thermometer. The sample was then allowed to cool below 0°C in an ice/salt bath. At this point it was removed and tilted on the clamp and the set up observed at intervals. The lowest temperature at which the oil was observed to flow was recorded as the pour point.

2.7.8 Cloud Point

An improvised method was used for the determination of this parameter (Ugah *et al.,* 2007). The cylindrical test tube was filled with the *Citrullus lanatus* seed oil to a specific level (10.00 ml) and clamped with wooden clamp bearing the thermometer. The test tube was placed in the ice/salt bath and the set up inspected at intervals for cloud formation. The temperature at which a distinct cloud appeared at the bottom of the test tube was observed and recorded as the cloud point of the oil.

2.7.9 Flash Point (F.P)

An improvised method was used for this determination (Ugah *et al.,* 2007). A 50 ml beaker was filled to a specific level (10.00 ml) with the seed oil and was heated at slow constant rate on the hot plate. The flash point was taken at the lowest temperature when an application of the test flame caused the vapor above the sample to ignite.

2.7.10 pH

The seed oil (10.00 ml) was measured in to the 50 ml beaker, the electrode of the meter was cleaned and dried, it was then introduced in to the sample and the reading was recorded (Schinas *et al.,* 2008)

2.8 Production of Fatty Acid Methyl Ester (Fames)

This method was adopted by Jauro and Haruna (2011) with slight modification.Potassium hydroxide (0.90 g) was weighed into a 150 ml conical flask; 180.00 ml of methanol was added slowly with continuous stirring, until the sodium hydroxide dissolved completely forming a sodium methoxide solution. The Potassium methoxide was added to 50.00 ml of *Citrullus lanatus* seed oil contained in a 150 ml conical flask and the mixture heated to a temperature of 50 ^{o}C with a slow but continuous stirring for about an hour. Care was taken not to stir vigorously in order to avoid emulsification. The mixture was then transferred into a separating funnel and allowed to stand for an hour. Two separate layers were formed; the lower layer (glycerin) was run down the tap leaving the upper layer (Biodiesel). Warm distilled water (30.00 ml) was added to the crude product (biodiesel), swirled slowly and allowed to stand for an hour. The lower water layer was runoff and the washing process repeated with cold distilled water until a clear product was obtained. The clear product was then passed through a funnel that was plugged with cotton wool and prayed with anhydrous magnesium sulfate on top in order to absorb any traces of water present and the final product was collected in a conical flask (Jauro and Haruna,2011). The yield was calculated as follows (Schinas *et al.,* 2008):

$$\text{\% yield of biodiesel} = \frac{\text{weight of biodiesel x 100}}{\text{weight of CPSO}}$$

2.9 Fuel Quality Parameters Tests

2.9.1 Flash Point (F.P)

An improvised method was used for this determination (Ugah *et al.,* 2007). A 50 ml beaker was filled to a specific level (10.00 ml) with the biodiesel and was heated at slow constant rate on the hot plate. The flash point was taken at the lowest temperature when an application of the test flame caused the vapor above the sample to ignite.

2.9.2 Cloud Point

An improvised method was used for the determination of this parameter (Ugah *et al.,* 2007). The cylindrical test tube was filled with the biodiesel to a specific level (10.00 ml) and clamped with wooden clamp bearing the thermometer. The test tube was placed in the ice/salt bath and the set up inspected at intervals for cloud formation. The temperature at which a distinct cloud appeared at the bottom of the test tube was observed and recorded as the cloud point of the oil.

2.9.3 Pour Point (P.P)

An improvised method was used for the determination of this parameter (Ugah *et al.,* 2007). The cylindrical test tube was filled with the biodiesel to a specific level (10.00 ml) and clamped with wooden clamp bearing the thermometer. The sample was then allowed to cool below 0°C in the ice/salt bath. At this point it was removed and tilted on the clamp and the set up observed at intervals. The lowest temperature at which the oil was observed to flow was recorded as the pour point.

2.9.4 Kinematic Viscosity

An improvised method was used for the determination of this parameter (Ugah *et al.,* 2007). The biodiesel seed oil was filled in to the clamped burette and was allowed to run freely in to a beaker. The time of the flow was recorded and the kinematic viscosity was calculated as follows;

Kinematic viscosity = Area of the burette/Time

2.9.5 Specific Gravity

An improvised specific gravity bottle was washed, rinsed with acetone and dried in the oven. The bottle was cooled at room temperature in a desiccator and the weight of the empty bottle was determined. The weight of the bottle filled with water was recorded. Then the water was poured out and the bottle was rinsed with acetone and dried in the oven. The same procedure was repeated with the biodiesel sample and the specific gravity computed as follows (Schinas *et al.,* 2008):

$$\text{Specific gravity} = \frac{W_1 - W_2}{W_3 - W_2}$$

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

2.9.6 Density

An improvised specific gravity bottle was washed, rinsed with acetone and dried in an oven. The bottle was cooled at room temperature in a desiccator and the weight of the empty bottle was determined on weighing balance. The weight of the bottle filled with the biodiesel was recorded. The volume of the oil in the bottle was also recorded and the density was computed as follows (Ugah *et al.,* 2007)

Density =(weight of bottle + oil) – weight of empty bottle/Volume of oil

2.9.7 pH

Biodiesel (10.00 ml) was measured in to a 50 ml beaker, the electrode of the meter was cleaned and dried, it was then introduced in to the sample and the reading was recorded (Schinas *et al.,* 2008).

2.9.8 Cetane Number (C.N)

This parameter was determined based on the formula proposed by (Demirbas, 1998). The formula is given below

$$CN = \frac{46.3 + 5458XI.V}{S.V - 0.225}$$

Where; S.V = saponification value of the oil, I.V = Iodine value of the oil

2.10 Biodegradability

2.10.1 CO_2 Evolution Method

The approach in this work followed the U.S. Environmental Protection Agency (EPA) standard method for determining biodegradability of chemical substances (EPA, 1992).

Shaker Flask System: A 2 dm^3 Erlenmeyer flask containing 900.00 ml de-ionized distilled water (DIW), 100 ml of inoculum (acclimation medium), 1ml of each stock solution (Table 1), and 10 mg/l carbon from the test compound was prepared (Table 1). A reservoir holding 10 ml of barium hydroxide solution was suspended in the flask to trap the CO_2.

Table 1: Medium employed for assay of CO_2 evolution from EPA (1992)

Stock Solution	Compound	Conc. (g/dm^3)
	NH_4Cl	35
i.	KNO_3	15
	$K_2HPO_4.3H_2O$	75
	$NaH_2PO_4.H_2O$	25
ii.	KCl	10
	$MgSO_4$	20
	$FeSO_4.7H_2O$	1
iii.	$CaCl_2$	5
	$ZnCl_2$	0.05
	$MnCl_2.4H_2O$	0.5
	$CuCl_2$	0.05
	$CoCl_2$	0.001
	H_3BO_3	0.001
	MoO_3	0.0004

2.10.2 Measurement of CO_2 Evolution

The method used was that adopted by Jauro and Haruna(2011) with slight modification. In this research, the quantity of CO_2 evolved was measured by titration of the entire $Ca(OH)_2$ sample (10.00 ml of $Ca(OH)_2$ plus 10.00 ml of rinse water) with 0.10 N HCl to the phenolphthalein end point. After sampling, the reservoir was refilled with fresh $Ca(OH)_2$. All the samples were analyzed at least five times in a 28-day period to provide sufficient data to determine biodegradation trend with time. Three ml of 20 % H_2SO_4 were added on the day prior to terminating the test. The percentage theoretical CO_2 evolved from the test compound was calculated at all the sampling times using the formula:

$$\% \ CO_2 \text{ evolution} = \frac{TF - CF \times 100}{C}$$

Where TF represents milliliters (ml) of 0.10 N HCl required to neutralize the $Ca(OH)_2$ from the flask with the test substance; CF represents milliliters (ml) of 0.10 N HCl required to neutralize the $Ca(OH)_2$ from the control flask; and C is the theoretical volume of the HCl required to neutralize the CO_2 converted from the carbon. For 10.00 mg carbon: C = 16.67 ml of 0.1 N HCl.

III. RESULT AND DISCUSION

3.1 Result

3.1.1 Physicochemical properties of Citrullus lanatus oil

Table 2.Physicochemical Properties of *Citrullus lanatus* Seed oil

Oil Quality Parameters	*Citrullus lanatus* seed oil	ASTMD Standard
% Moisture	2.83	
% Oil yield	43.67	<0.09
Color	Yellow-brown	
Odor	Pleasant fragrance	
Density g/cm^3	0.93	0.918 – 0.926
Kinematic viscosity mm^2/s	20.55	35
Cloud point °C	5	
Static viscosity mm^2ml/s	22.58	
Pour point °C	2	
Flash point °C	152	
pH	5.91	
Saponification value mgKOH/g	137.45$\pm$ 0.41%	189 - 198
% Free fatty acid	5.33$\pm$ 4.26%	25max
Iodine value $gI_2/100g$	40.91$\pm$ 2.87%	123
Acid value mgKOH/g	10.61$\pm$ 4.26%	10
Peroxide value Meq/kg	8.00$\pm$ 1.94%	< 9
Texture	Viscous texture to the feel	
Specific gravity	0.86	0.916

Values are mean $\pm$ coefficient of variation (n = 3)

3.1.2 Fuel quality parameters of Citrullus lanatus biodiesel

Table 3. The fuel quality parameters of *Citrullus lanatus* biodiesel is shown below.

Parameters	Produced Biodiesel	ASTMD Standard (ASTMD975)	Conventional (ASTMD6751)
% biodiesel yield	81	Reported value	Reported value
Kinematic viscosity $mm^{2/}s$	10.01	2–3	1.9 – 6.0
Density g/ml	0.87	0.82 - 0.845	0.86 - 0.90

Flash point °C	124	60–80	130–170
Cloud point °C	1.00	-15 to -5	-3 to -12
Pour point °C	0.00	-35 to -15	-15 to 10
Cetane number	76.80	40 – 55	47 - 65
Static viscosity mm^2ml/s	11.15		
Specific gravity pH	0.80 4.58	0.85	0.88

3.1.3 Biodegradability of Citrullus lanatus biodiesel.

Table 4. Carbon-dioxide (CO_2) evolved from the Produced Biodiesel after 28 days.

Days	Produced Biodiesel	Control	%Degraded
0	0.00	0.00	0.00
7	7.70±1.29%	7.25±2.07%	2.70%
14	3.60 ±9.72%	3.05+-1.64%	3.30%
21	8.30±1.2%	2.80±3.57%	32.99%
28	8.87±2.97%	2.40±4.80%	38.45%

Values are mean ± coefficient of variation (n=3)

3.2 Discussion

The oil of *Citrullus lanatus* is yellow-brown in colour with a pleasant fragrance. The percentage oil yield of 43.67 % obtained for *Citrullus lanatus* seed is very good. This value can be compared with the percentage yield per gram of rapeseed and soya-bean cultivated in Europe which is 37 % and 14 % per gram of oil respectively. The texture of the oil is viscous to the feel (Gerpen *et al.,* 2004).

The moisture content of *Citrullus lanatus* was found to be 2.83 % . accordint to BECON (2006) moisture contents of 6.5 to 7.5% gave the best compromise between the various considerations. Moisture content alongside free fatty acids is key parameters for determining the viability of vegetable oil trans-esterification process. The oil used in trans-esterification should be substantially anhydrous. This is because the presence of water gives rise to the hydrolysis of the esters produced, with consequent soap formation, which reduces catalyst efficiency, causes an increase in viscosity, leads to gel formation and makes the separation of glycerol difficult.

The oil has a specific gravity of 0.86 at 25^oC which is less dense than water. This is slightly different with those obtained for *jatropha* (0.88), coconut oil (0.91) and mango oil (0.92) (Hanna, 1994).

The density of watermelon seed oil was 0.93 g/cm^3 which differ slightly from that of hemp (0.81 g/cm^3) and neem (0.87), which are closer to the density of diesel (0.86 – 0.90) g/cm^3 (Omotoso *et al.,* 2011).

The saponification value of *citrullus lanatus* seed oil was found to be 137.45 meq/kg indicating moderate molecular weight of the fatty acid. The smaller the saponification number, the larger the average molecular weight of the tri-acyl glycerols present and vice versa. Value of 200 meq/kg and above indicate fatty acids of low molecular weight, while values less than 100 Meq/kg indicates fatty acids of high molecular weight. (Schinas e*t al*., 2008).

The Iodine value of 40.91 gI_2/100g for *Citrullus lanatus* seed oil shows that the triglyceride is liquid as it falls within (0 - 100) gI_2/100g.indicating that the oil can remain liquid at normal (room) temperature and is capable of forming elastic film after long exposure to air. Biodiesel made from oils with lower iodine values such as *Citrullus lanatus* seed oil are more efficient than those with higher values because they have higher cetane numbers. Therefore, *Citrullus lanatus* biodiesel may not be susceptible to oxidation and can be conveniently used if the biodiesel require long term application. Higher iodine value oils have lower melting points, but higher iodine value oils have higher risk of the biodiesel polymerizing (drying) into a tough insoluble plastic like solid. Biodiesel with high iodine value should be stored carefully and used quickly (Omotoso *et al.,* 2011).

From the result of peroxide value obtained, the triglyceride of *Citrullus lanatus* seed oil has a lower value of 8.0 meq/kg, this may be due to its freshness. Since the *Citrullus lanatus* seed oil has a lower iodine value therefore, *Citrullus lanatus* biodiesel and its oil are expected to be less susceptible to oxidation. The biodiesel made from it can be stored for a longer time.

The result of acid value was found to be 10.16 mgKOH/g which is lower than that of olive oil (17 mgKOH/g) and shea nut butter (10.3 mgKOH/g) (Schinas *et al.,* 2008).

The pH result of *Citrullus lanatus* seed oil was found to be 5.91, which shows that the oil is acidic.

This result is in agreement with the free fatty acid value of 5.048 mgKOH/g.

3.2.1 Fuel quality parameters of Citrullus lanatus biodiesel

The methyl ester (biodiesel of *Citrullus lanatus* is yellow-brown in colour. The result of the flash point of 152 °C was observed for *lanatus* , it is higher than that of palm oil and neem oil (Demirbas, 1998),which are higher than that of high speed diesel (60-80°C). For non-edible based seeds oils flash point are higher than fossil diesel (Gerpen *et al.*, 2004).

The cloud point of 5°C and the pour point of 2°C were observed for *Citrullus lanatus* seed oil biodiesel, it is higher than those of D2 with 0°C and -2 °C , respectively(ASTM, 2012). These indicate that the biodiesel may be suitable for use in tropical region like Nigeria.

The kinematic viscosity of 20.55 mm^2/s at 30 °C and the static viscosity of 22.58 mm^2ml/s at 40°C were observed for *Citrullus lanatus* seed oil biodiesel, which are higher than that of D2 (2.65 mm^2/s) For biodiesel to be used in diesel engines, the viscosity (at 40°C) must be between 1.9 and 6.0 mm^2/s (ASTM, 2012)..

The result of density of *citrullus lanatus* biodiesel was found to be 0.87 g/ml, it is closer to the density of diesel (0.845 g/ml) and it is less dense than water and can be used as an alternative fuel as it tallies with the ASTM standard for Biodiesel (0.86 - 0.92) g/ml (Biodiesel; Wikipedia, 2006).

The flash point of *Citrullus lanatus* biodiesel was found to be 124°C, which is lower than that of the conventional fuel (130-170) ^{o}C which shows that it is slightly flammable compared to the conventional D2 (ASTM, 2012). The typical flash point of pure methyl ester is greater than 200°C classifying them as non-flammable (BECON, 2006).

The cloud point of 1°C and the pour point of 0 °C for the biodiesel produced can be compared to -6°C and -9°C for castor oil biodiesel (Biodiesel, 2006). Pour point and cloud point of all biodiesel were almost within the specified range, while that of the conventional ranges from -3 to -12, (ASTM, 2012).

The result of viscosity of *Citrullus lanatus* biodiesel at 30°C was found to be 10.01 mm^2/s and a static viscosity of 11.15 mm^2ml/s, whereas the viscosities of castor bean oil biodiesel and pongam oil biodiesel are 5.67 and 5.5, respectively which are lower than the value obtained (Pitter and Chudoba, 1990). The viscosity of conventional D2 (at 40°C) is between 1.9 and 6.0 mm^2/s (ASTM, 2012).

The *Citrullus lanatus* biodiesel specific gravity of 0.804 at 30° C is in agreement with the specification for biodiesel and also this value agreed with value agreed at the Conference of fuel chemistry, which is 860 - 900 for biodiesel and 810 - 860 for petro-diesel (Biodiesel, Wikipedia, 2006).

. The cetane number obtained in this research is based on calculation using the formula given by (Demirbas, 1998). The value of 76.80 was obtained is higher than that of the conventional D2 47 - 65 and it meets the requirements for diesel fuels (ASTM, 2012).

The percentage yield of biodiesel from the watermelon seed was high, having 81 % as compared to 75.3 % for *Jatropha curcas* oil (Omotoso *et al.,* 2011).

The biodiesel was found to be acidic, with a pH of 4.58.

3.2.2 Biodegradability of Citrullus lanatus Methyl-Ester (Biodiesel).

The cumulative percent theoretical CO_2 evolved over 28 days from the biodiesel is found to be 38.45 % . This show that the maximum percent of CO_2 evolved within the 28 days period was 38.45 %. This indicates that as the days increase the biodiesel biodegradability increases significantly (from 2.70% to 38.45%). This indicates that the biodiesel fuel is inherently degradable (Degrade with time). The approximate days for complete degradation of this methyl ester will be 84 days which indicates that it will not be persistence in the environment.

IV. CONCLUSION

The preliminary investigation indicates that *Citrullus lanatus* seed oil is economically viable oil source because of its high oil content (43.67 %).

The specific gravity and acid value of *Citrullus lanatus*(10.61 and 0.86) is in agreement with the standard (10 and 0.916) as stated by the ASTM (2012), since the difference between the two is not too much, the oil may be suitable for the production of biodiesel. The *Citrullus lanatus* oil will make a good biodiesel because of its non- drying character and can be used on long term basis especially in hot weather.

The oil quality parameters show that the oil is composed of moderately long chain fatty acids with a moderate degree of unsaturation, thus low susceptibility to oxidative rancidity making it a good feedstock for biodiesel production.

The fuel quality parameters of the biodiesel (FAMES) indicate that the fuel can be used in some areas where temperatures are low or during cold period because of its low pour point and cloud point. The high flash point, show that it is free from the fire hazard associated with fuel during its transportation and storage.

The cumulative percent theoretical CO_2 evolution of 38.45% over 28 days from the biodiesel indicates that the biodiesel fuel will degrade faster with time, showing that it is not going to be persistent in the environment.

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