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Research Paper

Production and Characterization of Biodiesel from *Prunus amygdalus "dulcis"* Seed Oil

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***Abstract*—**In biodiesel production, the cost of feedstock accounts for the largest percentage of the production cost and there is a food-fuel strain on the utilisation of traditional oils (groundnut oil, palm oil and palm kernel oil) as feedstock. Hence, the use of under-utilised and less expensive feedstock provides a unique opportunity of significantly reducing such cost and strain. This research investigates the use of sweet almond (*Prunus amygdalus* "dulcis") seed oil as alternative feedstock for the production of biodiesel. The sweet almond seed oil was extracted via the solvent extraction method and trans-esterified using methanol with sulphuric acid as catalyst. The sweet almond seed has high oil yield (50%). The extracted oil has a specific gravity of 0.97 and low peroxide value (10.25±0.1 mMol/Kg) which are indications that it was of good quality. The fatty acid content of the seed oil revealed 61.62% of oleic acid predominantly present. Other fatty acids present are, linoleic acid (27.36%), palmitic acid (8.66%), palmitoleic acid (1.68%) and icosanoic acid (0.69%). The fatty acids composition shows a very high percentage (63.30%) of monounsaturated fatty acid in the extracted oil which makes it a good feedstock for biodiesel production. In the research, 83% biodiesel yield was achieved. The fuel properties of biodiesel prepared were also determined using standard test methods and were found to be within the ASTM and EN. Hence, Sweet almond seed oil can be a good dependable feedstock for biodiesel production.

Keywords*—Prunus amygdalus*, biodiesel, seed oils, fatty acids, physicochemical, almond

1. Introduction

Nigeria is one of the major oil giants and is embarking on biodiesel projects so as to join the League of Nations in benefitting from the advantages gained when biofuels are used. These projects include the blending up to 10% ethanol with fossil-fuel to achieve an E10 blend and a 20% blend of biodiesel with fossil-diesel to make a B20 blend [1].

The use of regular oils such as soybean oil, sunflower oil, palm oil, and rape seed oil for biofuels production is not uncommon [2], [3] and has often resulted in increase in prices and decrease in availability of these oils for food uses [4]. This has incite researchers to use waste oils, inedible oils and other lesser known oils in the preparation of biodiesel [2], [5], [6].

Seed oils of oil-bearing plants have been studied for use feedstocks for biodiesel production feedstock in Nigeria. Some of these oils are palm oil [7], palm kernel oil [8], egusi melon oil [9], coconut oil [10], tigernut [5], African mango nut oil [11] and Moringa oleifera [12]. Of all the oil-bearing crops commonly found in Nigeria, oil palm, palm kernel and groundnut are the most abundant and this is the reason for their selection as the preferred feedstocks for biodiesel production in the country's biofuel projects [1]. However, this is achieved at the expense of their use as food. Harnessing the neglected and inexpensive sweet almond seed as raw material for biodiesel production in Nigeria is therefore an effective way to reduce the food-fuel strain on the use of traditional oils (palm oil, groundnut oil and palm kernel oil) as well as a way of solving the problem of waste disposal while providing a biodegradable, renewable and eco-friendly fuel. The primary aim of this research is to investigate the use of this sweet almond (*Prunus amygdalus* "dulcis") seed oil as an alternative feedstock for the production of biodiesel in Nigeria.

Almond belong to the family *Rosaceae.* It is a species of *Prunus* which belongs to the subfamily of *Prunoideae*. Almonds consist of two main varieties. These are bitter almond (*Prunus amygdalus "amara"*) and sweet almond

(*Prunus amygdalus* “dulcis”). These are used primarily for cooking and oils making and as flavours respectively [13].

This paper has been organised into several sections. Section 1 includes review on some seeds oils used for biofuel production and justification of the need for biodiesel production using under-utilised seed oils. It also contains the aims of this research. The second section contains summary of related works on biodiesel production using almond seed oils and other seeds oils. The third section elaborates the method used in oil extraction, biofuel preparation and characterisation including those of fuel properties. Section 4 has detailed results and discussions on such results while the fifth section gives the conclusions and recommendation based on the findings of this work.

2. Related Work

Studies carried out that are related to this include investigation on the effects of different blend ratios on the fuel properties of almond biodiesel where the biodiesel was blended with petrol diesel at 20%. It was found that 20% blend had iodine value, acid value, viscosity, pour point and cloud point of 41.62gI_2/100g, 0.95meq/kg, 8.80Cp, 10^{o}C and 60^{o}C respectively [14].

A comparative study to evaluate the various performance parameters and the emissions of a diesel engine using fuel blends containing 0%, 10%, 30% and 50% in volume of almond biodiesel with diesel fuel has been carried out and the results compared to the results obtained using palm oil biodiesel [15]. In the research, the use of almond biodiesel resulted in improved performance as compared to palm oil and in terms of emissions, almond biodiesel resulted in lower carbon monoxide, oxides of nitrogen, total particulate and unburned fuel emissions in the exhaust gas.

In another study, the influence of fuel blends containing 10%, 30% and 50% almond oil biodiesel (B10, B30, and B50) with diesel fuel (B0) on emissions and performance parameters under various load conditions has been evaluated using a diesel engine. This study revealed that blend of almond biodiesel with diesel fuel gradually reduced the engine CO and total particulate emissions compared to diesel fuel alone [16].

In another related work, the extraction and characterization of oil from tropical almond seed shows that the seed contains 2.04 % moisture and 50.33 % oil. Other physicochemical properties of the extracted oil including density (0.90 g/cm3), specific gravity (0.89), kinematic viscosity at 40 ^{o}C (14.1 mPa.s), cloud point (16.0 ^{o}C), pour point (11.5 ^{o}C), saponification value (199.19 mgKOH/g), acid value (3.37mgKOH/g), free fatty acid (1.68 mgKOH/g), Peroxide value (5.0 meq/kg), and Iodine value (98.0 gI2/100g) was also investigated [17]. In the same study, biodiesel was prepared using the oil extracted and the fuel properties of the biodiesel which include density (0.96g/cm3), specific gravity (0.90), kinematic viscosity at 40 ^{o}C (5.20 mPa.s), kinematic viscosity at 100 ^{o}C (4.30 mPa.s), cloud point (7.0 ^{o}C), pour point (6.0 ^{o}C), smoke point (161.0 ^{o}C), flash point (186.0 ^{o}C), and fire point (216.0 ^{o}C) were investigated and then compared with the American Standard for Biodiesel Testing Materials (ASTM-D6751) standards.

Similar work have been carried out on other seed oils. These include synthesis and characterization of biodiesel from *Citrillus lantanus* seed oil where the fuel properties of the biodiesel prepared was investigated and compared with the American Standard for Biodiesel Testing Materials (ASTM-D6751) and the European Norm (EN-14214) standards. [18]. In another study [19], the physicochemical properties of sunflower seed oil were investigated.

3. Materials and Methods

Sample Collection and Preparation

Fresh and fully matured sweet almond fruits were collected from the front of the Biochemistry Laboratory of the University of Ilorin, Ilorin, Nigeria. The eatable fleshy parts were manually removed, leaving the stony shells containing the seed. The stony shells were cautiously broken and the seeds removed. The almond seeds were collectively sun-dried for about two weeks and then milled using a domestic blender. The almond seeds were pulverized and the oil was extracted from the seeds immediately.

Oil Extraction

The oil components of the milled seeds were extracted using a Soxhlet apparatus at 60 °C for 8 h with n-hexane. The solvent was removed from the oil at a temperature of 65 ºC under reduced pressure using rotary vacuum evaporator and the yield was calculated.

$$\text{Oil yield (\%)} = \frac{\text{Weight of oil extracted}}{\text{Weight of seed used}} \text{X100} \quad (1)$$

Fatty Acids Methyl Esters (Biodiesel) Preparation.

The trans-esterification reaction was carried out as described by [20] with slight modifications. 5 g of the seed oil was put into 250 mL round bottom flask attached to a reflux condenser, heater, magnetic stirrer and a thermometer. It was heated to 60 °C. 30 g of methanol containing few drops of concentrated sulphuric acid was added and stirred continuously for 1 h. The product was allowed to cool to room temperature and then transferred into a separating funnel. Using separating funnel, the bottom layer which contained glycerol and top layer which contained the prepared fatty acid methyl esters were separated. Gently, the fatty acid methyl esters was washed thrice using warm distilled water to ensure that residual catalyst or soaps that may be present have been removed and stored for GC-MS and other analysis.

$$\text{Biodiesel yield(\%)} = \frac{\text{Weight of methyl ester prepared}}{\text{Weight of oil used in reaction}} \times 100 \quad (2)$$

Specific Gravity Determination.

The specific gravity (S.G.) of both the crude oil and biodiesel were evaluated. A clean 50 mL specific gravity bottle was weighed while empty, when filled completely with water, and then when filled with oils. S.G. of the oils were calculated [21].

$$\text{Specific gravity} = \frac{W_2 - W_0}{W_1 - W_0} \quad (3)$$

W_0 = Weight of empty S.G. bottle
W_1 = Weight of the water + the S.G bottle
W_2 = Weight of the test sample + S.G. bottle.

Determination of Kinematic viscosity (ASTM D445)
The kinematic viscosity was carried out for both crude oil and biodiesel using Ostwald viscometer. The viscometer was washed and calibrated with distilled water and the calibration constant of the viscometer was noted. The temperature of the room was taken (27 ^oC) and the oil was introduced into the viscometer and adjusted (sucked) to a point in the capillary arm about 5mm ahead of the first timing mark. The oil was allowed to flow freely. The time taken for the meniscus to move from the first to the next was recorded [22].

$$V = C^4 t. \quad (4)$$

V = kinematic viscosity (centistoke)
C = viscometer calibration constant
t = time of flow (seconds)

Determination of the Flash point and the Fire point (ASTM D 93)
The prepared biodiesel was poured into a strong resistance glass cup and a thermometer was placed in the oil and heated. The test flame was passed over the cup at every 2 ^oC increase in the oil temperature. When the oil vapours ignite momentarily in air, the flash point temperature is reached and when the oil vapours sustain combustion for at least five seconds, the fire point temperature is reached and noted [22].

Determination of Refractive index (ASTM D1218-92)
Refractive index of both crude oil and biodiesel was measured. The oils were applied to the faces of two prisms after cleaning them. A light source was used and the reading was taken directly from the scale [22].

Colour Determination
Colour of the oils were physical observed in daylight and in ultraviolet chamber (at 254 and 366 nm) [6].

Determination of Cloud Point (ASTM D 2500)
A test jar containing a small sample of the prepared biodiesel was placed in a cooling bath while monitoring the temperature at the bottom of the test jar. The temperature at which the fuel begins to form cloud is noted and recorded [22].

Determination of Pour Point (ASTM D 97)
A small portion of the oil was placed in a freezer at a temperature of about 5 ^oC then melted by placing on a heating mantle while taking note of the temperature at the bottom of the test jar. The temperature at which the oil began to pour was noted and recorded [22].

Acid Value Determination
The acid value test was carried out on both the crude oil and the biodiesel. Petroleum ether was mixed with same volume (25mL) of ethanol and 4 drops of phenolphthalein indicator in a flask that contained 2g of the oil. The mixture was titrated against 0.1M KOH solution with proper shaking till a pink colour which persisted for 15 seconds was observed [23].

$$\text{Acid value} = \frac{56.5 \times V \times N}{\text{Weight of oil}} \quad (5)$$

V= volume of standard base in mL
N= normality of the standard base

Saponification Value Determination
The saponification value (SV) was determined for both crude oil and biodiesel. 1 g of oil sample was dissolved into 12.50 mL of 0.5 M ethanolic potassium hydroxide. The mixture was refluxed until oil droplets disappear and was left to cool to room temperature. The solution was titrated with 0.5 M HCl using phenolphthalein indicator until the pink colour disappears. A blank titration was similarly done [24].

$$\text{Saponification value} = \frac{(B\text{-}S) \times 56.10 \times M}{W} \quad (6)$$

B= Volume (mL) of hydrochloric acid used in the blank titration.
S = Volume (mL) of hydrochloric acid used in the titration.
M = Molarity of hydrochloric acid.
W = Weight of sample used (g).

Iodine Value Determination
The Iodine value determination for both the crude oil and the diesel was carried out. 10 mL of chloroform and then 30 mL of Hanus iodine solution was added into a 250 mL conical flask containing 0.25 g of the oil. With the flask sealed properly, its content was shaken while in the dark for about 30 minutes. 10 mL of 15% potassium iodide solution was added and then shaken. This was followed by the addition of 100 mL of distilled water and the resulting solution was titrated with 0.1 N Sodium thiosulfate solution until there is a change to yellow colour. 2-3 drops of starch solution was then added which gives a blue solution and the titration was resumes until the blue colour had disappeared [25].

$$\text{Iodine value} = \frac{(B\text{-}S) \times C \times 12.69}{W} \quad (7)$$

C = concentration of $Na_2S_2O_3$.
B = volume of $Na_2S_2O_3$ used for titrating blank
S = volume of $Na_2S_2O_3$ used for sample
W = weight of sample.

Peroxide Value Determination
The Peroxide values (PV) of the crude oil as well as that of the biodiesel was determined. 30 ml of glacial acetic acid and chloroform (3:1) was added into 200ml conical flask containing 5 g of oil and thoroughly mixed. 0.5 mL of saturated potassium iodide was added to the mixture and kept in the dark for a minute while swirling periodically. 30 ml distilled water was added. This was titrated with 0.1 M sodium thiosulphate solution using 1 % starch solution as an indicator until the blue colour disappears. A blank titration was similarly carried out [26].

$$\text{Peroxide value} = \frac{(B-S) \times 10}{W} \quad (8)$$

B = Volume (mL) of sodium thiosulphate used in blank titration.
S = Volume (mL) of sodium thiosulfate used in titration.
W = weight of oil used.

4. Results and Discussion

Physicochemical Characteristics of Seed Oil

Table 1: Physicochemical Properties of the Sweet Almond Seed Oil Extracted

Properties	Almond seed oil
Oil yield%	51%
Specific Gravity	0.97±0.02
Refractive index	1.46
Colour	Yellow
Kinematic Viscosity (mm^2/sec)	24.40±0.05
Iodine Value (gI_2/100g)	108.46±1.7
Acid Value (mgKOH/g)	16.3±0.2
Peroxide Value (mMol/Kg)	10.25±0.1
Saponification value (mg/g)	164.56±1.6

Table 1 shows the physicochemical characteristics of the extracted sweet almond seed oil. The sweet almond seed have high lipid content (51%). This is similar to that found in Siberian apricot (51.15%) [27], *Moringa oleifera* (51%) [12], palm kernel (50%) [1] and egusi melon (51%) [12]. However this lipid content is much higher than what was found in soybean (17%) [28], cotton (15%) [28] as well as tigernut (16%) [5]. This yield implies that Almond seed is suitable as a source of oils for applications that require it in large quantities.

The specific gravity of *Prunus amygdalus* seed oil was 0.97 which is similar to the findings (0.9844) reported for bitter melon seed oils [29]. This value is higher than 0.94 found in mango seed oil [30]. The results show that oils of almond seed are of high purity since they are less dense than water and will float on water in case of a spill. The refractive index is 1.46 which is similar to 1.47 for water melon seed oil [31] and 1.46 reported for Almond [32] and Water melon [26] seed oils respectively. The colour of an oil is used as a preliminary test to determine its quality and how much bleaching it requires [33]. Darker colour indicates poorer quality [34]. Therefore the yellow colour obtained for almond seed oil is an indication of good quality. Kinematic viscosity gives the extent a fluid resists flow under gravity [35]. The kinematic viscosity of the oil investigated is 24.40 cSt (measured at 27 ^{o}C). This is lower than 38 cSt (measured at 40 ^{o}C) [36] and 25.74 cSt (also measured at 40 ^{o}C) [20] reported both for *Parinari polyandra* oil. It is also lower than 32.6 cSt, 33.07 cSt and 29.4 cSt (all measured at 40 ^{o}C) found for sunflower oil [37], rapeseed oil [37] and olive oil [37].

Iodine value measures the degree of saturation of the oils as well as their potential to oxidise when they are exposed to air [38]. The iodine value of Almond seed oil was found to be 108.46±1.7 gI_2/100g. This is lower than 121.8 gI_2/100g [39] and 157.15 gI_2/100g [26] both reported for water melon seed oils. Acid value directly measures the quantity of free fatty acids in an oil. It indicates to what degree the triglycerides in the oil have been converted to free fatty acids [24]. The acid value of the seed oil was 16.3±0.2 mgKOH/g. This value was higher than the values (10.096 mgKOH/g [39] and 2.08 mgKOH/g [26]) reported for water melon seed oils. The peroxide value for the almond seed oil was 10.25±0.1 mMol/Kg. This is higher than 2.25 mMol/Kg reported for almond seed oil by [32]. It is also higher than 3.02 mMol/Kg [40] and 0.22 mMol/Kg [41]. However, the peroxide value found is lower than 22 mMol/kg reported for *Citrullus vulgaris* seed oil [42]. Fresh oils have values less than 10 mEq/Kg and values between 20 mEq/Kg and 40 mEq/Kg results in rancid state [43]. The low peroxide values of the oil indicates that at room temperature, it is less vulnerable to oxidative rancidity [44], [45]. The saponification value obtained for the sweet almond seed oil is 164.56±1.60 mgKOH/g. This is lower than that of sunflower oil (192.1 mgKOH/g), rapeseed oil (170.4 mgKOH/g) and olive oil (196.2 mgKOH/g) [37]. This finding is also lower than 185.545±1.465 mgKOH/g [29] and 190.70 mgKOH/g [46] for oils of bitter melon seed. The saponification values of seed oils indicate the foaming property of the oils and foaming is one of the characteristic desired in surfactants useful for applications in the formulation of soap, detergents and emulsions [47].

Fuel Properties of the Prepared Biodiesel

Table 2: Fuel Properties of Biodiesel Produced from Sweet Almond Seed Oil

Properties	Produced biodiesel	ASTM D 6751 Limit	EN 14214 Limit
% yield	83%	-	-
Specific Gravity	0.834±0.019	0.88	-
Refractive index	1.46	-	-
Colour	Clear yellow	-	-
Flash point (^{o}C)	120±5	130 minimum	101 minimum
Cloud point (^{o}C)	-10±0.3	-3 to -12	-
Pour point (^{o}C)	-3±0.2	-15 to -16	-
Physical state of the oil	Liquid	-	-
Kinematic Viscosity (cSt)	4.14±0.14	1.9 to 6.0	3.5 to 5.0
Iodine Value (gI_2/100g)	89.85±0.7	-	-
Acid Value (mgKOH/g)	0.23±0.02	0.5 maximum	0.5 maximum
Peroxide Value (mMol/Kg)	2.7±0.3	-	-
Saponification value (mg/g)	151.55±0.03	-	-

Table 2 shows the fuel characteristics of the biofuel prepared from the extracted sweet almond seed oils. The percentage yield of the biodiesel prepared is 83%. This is higher than the 75.3% for groundnut oil biodiesel [48] and 79% for jatropha seed oil biodiesel [49]. However, it is lower than the 88% reported for groundnut oil biodiesel [50] and 85.9% reported for almond seed oil biodiesel [51]. The high yield obtained in this work is an indication that the sweet almond seed oil is an excellent feedstock for biodiesel preparation.

Specific gravity is one of the most basic and most important characteristics of fuels [52] because it correlates with fuel storage, heating values, cetane number and transportation [53], [54]. The specific gravity of the almond seed oil biofuel in this study (0.834±0.019) is lower than 0.88 reported as biodiesel ASTM standard [35] and 0.881 reported for biodiesel prepared from mango seed oil [30]. However, this finding is similar than 0.84 reported for jatropha biodiesel [55]. Refractive index (R.I) is a parameter used for standardisation of fuels and is used to determine the state of a biodiesel given that the R.I changes when the cloudy state appears as the temperature of the biofuel approaches the cloud point [56]. The biodiesel produced in this research has R.I value of 1.46. This is same as the R.I value reported for soya bean oil biodiesel [57] and watermelon seed biodiesel [26]. The colour of the biodiesel prepared is yellow. This colour is same as that of palm oil biodiesel [23] and water melon seed biodiesel [26].

The lowest temperature that an oil must be heated to before its vapour-air mixture ignites is the flash point of such oil [38]. The Flash Point of the biodiesel prepared in this study is 120 °C. This is lower than 170 °C for palm oil biodiesel [23]. It is also lower than 178 °C, 181 °C and 182 °C reported respectively for biodiesels of sunflower oil, rapeseed oil and olive oil [37]. The value also falls below the ASTM (>130 °C) standard limit but within the EN (>101 °C) standard limit for biodiesel. The fire point for the biodiesel produced is 210 °C. This is lower than the 123 °C reported for watermelon seed oil biodiesel [26]. Pour point (PP) of a fuel oil refer to the lowest temperature at which a fuel stops flowing. This is a very important determinant of cold flow operation since the fuels can only flow at temperatures above their pour. Biodiesels in general have higher cloud point as well as pour point compared to fossil-diesel [38] and both of these characteristics are relevant in the handling of biodiesel in colder regions. The biodiesel prepared has a cloud point of -10 °C. This is lower than 12 °C [30], 3 °C [57] and 8 °C, [55], for biodiesels produced from mango seed oil, shea nut butter and jatropha oil respectively. The pour point is -3 °C. This is lower than -6 °C, -8 °C and -5 °C found respectively for sunflower oil biodiesel, rapeseed oil biodiesel and olive oil biodiesel [37]. The pour point as well as the cloud point of the biodiesel in this work have been found to be within the range (-15 ^{o}C to -16 ^{o}C and -3 ^{o}C to -12 ^{o}C respectively) of the ASTM Standard [54]. Kinematic viscosity of the sweet almond seed oil biodiesel produced is 4.14 cSt. This is within the ASTM standard (4-6 cSt) and close to the values (4.42 cSt and 4.82 cSt) reported for shea nut butter biodiesel [58] and jatropha seed oil biodiesel [55]. However, the value is lower than 5.82 cSt for biodiesel prepared from mango seed oil [30]. Low viscosity fuels provide good lubrication while high viscosity fuels partially combust, causing increased in exhaust emissions and buildup of fuel in engine [30].

The biodiesel prepared in this study has iodine value (IV) of 89.85 ±0.7 gI_2/100g. This is lower than 120 gI_2/100g standard iodine value reported as Europe's EN 14214 specifications [59] and as ASTM D6751 [60] for standard fuels. IVs are determinants of viscosities and cloud points. Fuels with lower IV are better biodiesels. Fuels with IVs greater than 50 decrease engine life but they provide better viscosity needed in cooler conditions [61]. The acid value obtained for biodiesel prepared in this work is 0.23 mgKOH/g. This value is lower than 0.28 mgKOH/g, and 0.35 mgKOH/g respectively for shea nut butter biodiesel [58] and rapeseed oil biodiesel [37]. Acid value is a direct measures of the amount of free fatty acid in a biodiesel. It is also useful in determining the quality of the biodiesel. A high acid value means that the fuel is of low quality [30]. Peroxide value (PV) of biodiesels measures the quantity of peroxides produced when the air (oxygen) reacts with fatty esters, initiating the oxidative degradation of the biodiesels [62]. The PV of the biodiesel produced is 2.7 mMol/Kg. This is lower than that (3.96 meq. O_2 kg^{-1}) reported for biodiesel made from waste frying [62]. The saponification value of the biodiesel produced from sweet almond seed oil is 151.55±0.03 mgKOH/g. This is lower than 154 mgKOH/g obtained for water melon seed oil biodiesel [26] and 193.55 mgKOH/g obtained for biodiesel prepared from jatropha seed oil [63]. It is much lower than 244.74 mgKOH/g obtained for groundnut oil biodiesel [48].

Fatty acid profile of almond seed oil

Table 3: Fatty Acid Profile of Almond Seed Oil

Fatty acids	Saturation	%RA of *Prunus amygdalus*
Palmitic acid	16.0	8.65
Palmitoleic acid	16:1	1.68
Oleic acid	18.1	61.62
Linoleic acid	18.2	27.36
Icosanoic acid	20:0	0.69
Total unsaturated		90.66
Total monounsaturated		63.30

%RA = Percentelative Abundance

Table 3 shows the fatty acids content of the sweet almond seed trans-esterified oils. Oleic acid (61.62%) and linoleic acid (27.36%) are the most dominant among the fatty acids present in sweet almond seed oils. Although most (90.66%) of the fatty acids present are unsaturated, 63.30% of the fatty acids are monounsaturated. Oils with high percentages of monounsaturated fatty acids are good feedstock for biodiesel production [64], [65], [66]. Consequently, with high monounsaturated content, almond seed oil represents a good feedstock for biodiesel production.

5. Conclusion and Future Scope

This study has been carried out to prepare biodiesel from sweet almond seed oil by acid-catalysed transesterification of the extracted oil. Both the oil extracted and the biofuel produced were characterised and the biodiesel was compared to the ASTM standards. The sweet almond seed has high oil yield (50%) and so can be reliably used as oil source. No rancidity of oil sample was found during the period of this study which indicates that the oils can be stored for a long time. The lack of rancidity is also indicated by the low peroxide value (10.25±0.1 mMol/Kg) of the oil. The specific gravity is 0.97 which means that the oil obtained it is lighter than water and of high purity. Moreover, a very high percentage (63.30%) of the fatty acids in the extracted oils is monounsaturated which is specifically a good feedstock when used in biodiesel production. The biodiesel has a very high yield 83%. The fuel properties of the sweet almond seed oil biodiesel prepared such as cloud point and kinematic viscosity fall within the ASTM standards. The flash point is lower when compared with the ASTM standard value but falls within the EN standard value while the pour point is higher than the ASTM standard value. Further studies should be carried out on performance evaluation of biodiesel prepared from almond seed oils in diesel engines.

Data Availability

To facilitate reproducibility, further analysis, validation, collaboration and the advancement of knowledge in this field, data on this research will be available and accessible through the designated channels upon request.

Conflict of Interest

The authors of this work declare no conflict of interests and this work has not been submitted for publication to any other journal.

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Authors' Contributions

Oloruntele Ibrahim Opeyemi and Muhammad Ibrahim Hamza researched literature. Oluwaniyi Olusola Omolara and Oloruntele Ibrahim Opeyemi conceived the study and developed the research protocols. Oloruntele Ibrahim Opeyemi and Muhammad Ibrahim Hamza analysed the data. All the authors reviewed, edited and approved the final version of the manuscript for publication.

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