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Potentials of Oil Extracted from Sawdust as Feedstock for Biodiesel Production

O.D. Ogundele,[1*] A.B. Sobogun,[1] and J.O. Jayeola[2]

[1]Department of Chemical Sciences, Achievers University, Owo, Ondo State, Nigeria

[2]QC/HSE Department, Ibafon Oil Limited Lagos, Nigeria

*E-mail: olusoladavidogundele@gmail.com

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ABSTRACT

Pollution being a global problem facing the world, there is the necessity for substitution of fossil fuel with more efficient fuels that are eco-friendly and renewable (biofuel). This research aims to turn waste to wealth and provide a green approach to fuel. Saw dust was collected from a local saw-mill in Owo, Ondo state Nigeria and characterized. The result obtained from the physicochemical analyses of the saw dust showed moisture content 10.58%, pH 8.23, tap density 0.43, bulk density 0.32, true density 1.36g/dm^3 and compressibility index 20.33%. Afterwards, oil was extracted through soxhlet extraction using n-hexane as a solvent with 0.1M, 0.2M and 0.3M NaOH as catalyst. The percentage yield of the extracted oil with 0.1M NaOH (Oil_a), 0.2M NaOH (Oil_b) and 0.3M NaOH (Oil_c) were 13.20%, 14.03% and 15.57% respectively. The specific gravity of the oil range from 0.80 (Oil_c)-0.91 (Oil_a), viscosity 4.50-4.70, refractive index 1.37-1.52, flashpoint 132-136^{0}C, saponification value 161-171 mg KOH/g and iodine value 118-134 mg I/g. The extracted oil was used for the production of biodiesel via base-catalyzed transesterification using ethanol and NaOH. The physicochemical properties of the produced biodiesel were analyzed for specific gravity (0.849), kinematic viscosity (2.9), acid value (0.502 mgKOH/g), cetane number (45.82), cloud point (5.07 ^{0}C), flash point (140^{0}C). From the results obtained in this study, the physicochemical properties of the produced biodiesel were within ASTM recommended values, indicating a quality fuel production.

KEYWORDS: Sawdust; Oil; Biodiesel; Feedstock

1. Introduction

The consumption of energy has increased a lot due to the change in the life style and the significant growth of population. This increase of energy demand has been supplied by the use of fossil resources, which caused the crises of the fossil fuel depletion, and the serious environmental impacts as global warming (Banerjee *et al.,* 2002). As fossil fuels are limited sources of energy, this increasing demand for energy has led to a search for alternative sources of energy that would be economically efficient, socially equitable, and environmentally sound (Bilad *et al.,* 2014).

The demand for transport fuel has been increasing and expectations are that this trend will stay unchanged for the coming decades (Cheng and He 2014). In fact, with a worldwide increasing number of vehicles and a rising demand of emerging economies, demand will probably rise even harder. Transport fuel demand is traditionally satisfied by fossil fuel demand. However, resources of these fuels are running out, prices of fossil fuels are expected to rise and the combustion of fossil fuels has detrimental effects on the climate (Chisti, 2007). The expected scarcity of petroleum supplies and the negative environmental consequences of fossil fuels have spurred the search for renewable transportation biofuels' (Abodeely *et al.,* 2006).

Biofuels appear to be a solution to substitute fossil fuels because, resources for it will not run out (as fresh supplies can be regrown), they are becoming cost wise competitive with fossil fuels, they appear to be more environmental friendly and they are rather accessible to distribute and use as applicable infrastructure and technologies exists and are readily available (Bahadar and Khan, 2013). Forecasts are that transport on a global scale will increase demand for conventional fuels with up to a maximum annual growth of 1.3% up to 2030. This would result in a daily demand of around 18.4 billion liters (up from around 13.4 billion litres per day in 2005) (The Royal Society, 2008).
Biomass can be used for energy in several ways; one of these is the conversion into liquid or gaseous fuels such as ethanol and bio-diesel for use in mobile source combustion (Manzanera *et al.,* 2008).

Biofuels is more environment friendly in comparison to fossil fuels considering the emission of greenhouse gasses when consumed (Chisti, 2007). The energy content of biofuels differs from conventional fuels. Total energy output per liter of biofuel is determined by the feedstock used, region where the feedstock is grown and production techniques applied. Beuckels *et al.* (2015) provides, for example, energy contents of biodiesel and bioethanol. Biodiesel has an energy ratio compared to diesel of about 1.1 to 1, which means that its energy contents are 87% of those of diesel. Bioethanol has an energy ratio compared to gasoline of 1.42 (67% of gasoline). The amount that is similar to the amount of energy content of one-liter gasoline is referred to as gasoline equivalent (Chisti, 2007). Pollution being a global problem facing the world at large (Thompson *et al.,* 2019), there is the necessity for substitution of fossil fuel with more efficient fuels that are eco-friendly and renewable (biofuel). This research aims to turn waste to wealth and provide a green approach to fuel.

2. Materials and Methods

2.1 Sample Collection and Preparation

The raw material (sawdust) was obtained from a local sawmill in Owo, Ondo state. The sawdust was air-dried for seven days to reduce the moisture content in it. Afterwards, the air-dried sawdust was sieved using a mechanical sieving machine with sieve size 850 micron to enable us get a finer particle of sawdust with equal sizes.

2.2 Methods

2.2.1 Analysis of Sawdust Sample

2.2.1.1 pH

Exactly 5 g of powder was dispersed in 50 mL distilled water with continuous stirring for 1 h. The pH was determined with a pH meter (Anaun and Ogundele, 2021).

2.2.1.2 Moisture Content

An empty crucible with its cover was dried in the oven at 105 ^{0}C and weighed (W_1). Exactly 5 g of the sample was then added to the already weighed crucible, dried for 3 h in an oven at 105 ^{0}C, cooled in a desiccator and weighed (Emmanuel *et al.,* 2020). The crucible and its content were returned to the oven for 1h and the cooling was repeated and weighing was done. This process was repeated successively until a constant weight was obtained (W_2) (Ogundeleolusola *et al.,* 2019). Moisture content was determined using equation 3.1:

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100\ \% \text{......... 2.1}$$

Figure 1: Saw dust Powder

2.2.1.3 True, Bulk and Tapped Densities

True, bulk and tapped densities were determined using Dagwa *et al.* (2012). The true densities (ρt) of the saw dust were determined by the liquid displacement method using xylene as the immersion fluid and computed.

$$\rho t = \frac{w}{[(a+w)-b]} \times SG .... 2.2$$

Where w is the weight of powder, SG is specific gravity of xylene (0.8802), a, is weight of pycnometer + xylene and b is weight of pycnometer + xylene + saw dust powder. (Ohwoavworhua and Adelakun, 2005). The weight of pycnometer filled with xylene was determined and 1 g of the sawdust was transferred into the xylene filled pycnometer and the weight determined. The true density was then evaluated.

2.2.1.4 Compressibility Index

Compressibility Index (CI) was determined using Dagwa *et al.* (2012) method using the equation:

$$CI = \frac{\text{tapped density} - \text{bulk density}}{\text{tapped density}} \times 100 ....2.3$$

2.3 Extraction and Analysis of Oil

The extraction of oils from the saw dust was carried out using Soxhlet extraction apparatus. A 100 g of the saw dust sample was put into a porous thimble and placed in a Soxhlet extraction apparatus, using 150 mL of n-hexane (with boiling point of 40 - 60 ^{o}C) as extracting solvent for 6 hrs, this process was repeated using Sodium Hydroxide as catalyst (concentration of 0.1M, 0.2M and 0.3M). The oil was obtained after the solvent was removed using water bath. The oil was then stored in freezer at -2 ^{o}C for subsequent physicochemical analyses (Anaun and Ogundele, 2021). After extraction, the samples were analyzed according to the official methods of analysis described by Association of Official Analytical Chemist (A.O.A.C 1990). All analyses were carried out in triplicate.

2.4 Production and Analysis of Biodiesel

The crude saw dust oil was heated to 50 °C with continuous stirring to homogenize the oil on a magnetic stirrer. Concentrated sodium hydroxide (2 %) the weight of oil was added to methanol (61.6 mL), heated and stirred for one hour to a maximum temperature of (60-65 ^{o}C) not exceeding the boiling point of ethanol (Scarlat *et al.*, 2015). The ethanol - base mixture was transferred into the pre-heated oil (Rominiyi *et al.*, 2017). The reaction mixtures were turned into a separating funnel to settle for three hours. A clear separation in different layers was observed, the top layer contained mainly water and ethanol and the bottom layer contained esterified oil (Fukuda *et al.*, 2001). After biodiesel production, the biodiesel was analyzed according to the official methods of analysis described by Association of Official Analytical Chemist (A.O.A.C, 1990). All analyses were carried out in triplicate.

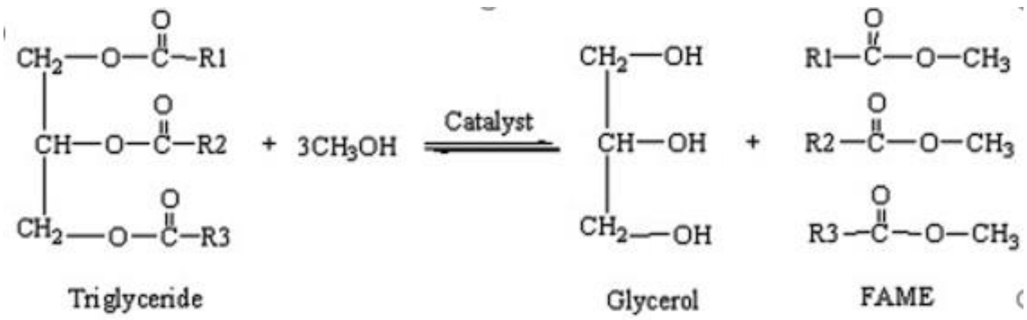

Figure 2: Transesterification

2.5 Statistical Analysis

All analyses were done in triplicate to evaluate experimental reproducibility and reported as Mean ± Standard Deviation. The data obtained were subjected to one-way analysis of variance (ANOVA) using SPSS version 21. Duncan's multiple range test was used to determine means that were significantly different at a level of significance (α) of 0.05.

3. Results and Discussions

3.1 Physicochemical Analysis of Sawdust Sample

The results of the physicochemical analysis of the sawdust powder are as presented in Table 1.

The percentage moisture content of the sawdust gave a value of 10.58%. The moisture content obtained in this research is lower than that of Brindha *et al.* (2012) where a value of 11.25% obtained from Rasthali Banana. The value is higher than 5.7% obtained by Akowuah *et al.* (2012) for sawdust charcoal briquette. The differences in results obtained may be attributed to difference in sample used, harvest time, method of drying and atmospheric condition. The result indicates that sawdust sample may have long shelf life because high moisture content enhances the activities of microorganisms which can reduce the shelf life of the sawdust.

The pH of the sawdust sample gave a value of 8.32. The pH value gotten in this research is higher than that obtained by Ikenyiri *et al.* (2019) where a pH value of 5.48 was gotten. From the result presented, it shows that the pH value of the sawdust sample is slightly basic compared to that obtained by Anaun and Ogundele, (2021) which gave a neutral pH of 7.56. The basic nature of the sawdust sample could be as a result of the moisture content, the structural and chemical composition of the wood. This result shows that the sawdust sample can be used for the correction of soil pH. pH is an important variable in the environment and also in biodiesel production.

Sawdust sample result revealed that it had a tap density of 0.43. The value is higher than 3.12 which was obtained by Dagwa *et al.* (2012) and lower than 0.62 from *Elaeis guineensis dura* shell. Tap density which refers to the maximum packing density of a powder achieved under the influence of well-defined, externally applied forces depends on a number of factors including particle size distribution, true density, particle shape and cohesiveness due to surface forces including moisture. The result can be used to predict both its flow properties and its compressibility.

The result obtained showed the value of bulk density as 0.32. The value is lower than 0.84 which was obtained by Ikenyiri *et al*. (2019). The value was also observed to be lower than 0.60 reported by Kong *et al*. (2013) in the study of *Elaeis guineensis dura* shell. The bulk density of this material is a major factor to consider when characterizing flow ability, stacking and storage, since it is not an intrinsic property of a material i.e. its measured as a dry weight per unit volume. It was observed that the result obtained shows a relationship between the true density and the bulk density. The result reflects the ability of the material to function as structural support, water and solute movement and aeration.

Sawdust sample was observed to have a lower true density of 1.36 compared to 1.58 earlier reported by Dagwa *et al.* (2012) where palm kernel shell powder was studied.

The study of the compressibility index revealed that the sawdust sample has a higher C.I of 20.33 than 18.58 earlier reported by Dagwa *et al*. (2012). These values fall within the range of fair flow ability based on the scale of flow ability (Dagwa *et al.,* 2012). The compressibility index is related to the true density and bulk density. It was observed that the compressibility index increases with decreasing true density and bulk density i.e. the denser the powder the lower the compressibility index.

3.2 Physicochemical Analysis of Extracted Oil

The result obtained showed that Oil_c had the highest yield of 15.57% which was higher than Oil_b 14.03% and Oil_a 13.20%. the variation in the result is due to the different concentration of the NAOH catalyst used during the extraction. 0.1M of NAOH was used for Oil_a, 0.2M for Oil_b, 0.3M for Oil_c. the percentage yield for Oila and Oil_b is quite similar. The result shows that the highest yield of Oil_c can be related to the high centration of catalyst used during the extraction.

The pH showed Oil_a as 7.30, Oil_b as 7.90 and Oil_c as 8.30. this result shows that Oil_c has the highest PH which makes it more basic than the rest. The study shows that Oil_a and Oil_b would not interact with acidic or basic medium. It is known that water soluble oils which are slightly alkaline have a pH range of 8.50 to 9.0. pH is an important variable in the environment.

The study of the specific gravity revealed that Oil_a had a higher S.G of 0.91 than that of Oil_b 0.85 and Oil_c 0.80. the specific gravity obtained from Oil_a is exactly the same with 0.91 which was earlier reported by Eboibi *et al.* (2018) for jatropha oil. It was observed that Oil_b and Oil_c had a similar result for S.G. Specific gravity which is also called relative density is the ratio of the density of the liquid to the density of water at 4^0C. The ability of an object to float in water or air is related to its specific gravity.

From the study Oil_b had the highest value of 1.52 followed by Oil_c which was 1.49 then Oil_a which was 1.37. the refractive index of Oil_a and Oil_c is different from 1.46 that was reported by Acevedo *et al*. (2018) for waste frying oil but the R.I of Oil_c is quite similar. It was also observed that Oil_a and Oil_c had a value different from 1.45 reported by Eboibi *et al.* (2018) for jatropha oil but it was quite similar to Oil_c. refractive index indicates the possible chances of rancidity development in oil. The higher the refractive index, higher the chances of spoilage due to oxidation. refractive index is an important optical parameter to analyze the traversing through the materials medium.

Oil_a was observed to have the highest viscosity of 4.70 followed by 4.50 for Oil_b and 4.50 for Oil_c also. All these values are lower than 52.89 which was reported by Acevedo *et al*. (2018) for waste frying oil. This difference in the viscosity may be due to the biomass used. It was observed from the obtained result that the viscosity increases with percentage yield. The higher the viscosity, the higher the thickness. The change in viscosity can be explained by the variation in the concentration of catalyst used. Viscosity is the measure of an oil resistance to flow, it refers to how easily oil pours at a specified temperature. It is important because it determines the oil's film strength and efficiency in preventing friction.

This study indicates that Oil_a had the highest flashpoint of 136 followed by Oil_b 135 and Oil_c 132. From the result it was observed that the three flash points of Oil_a, Oil_b and Oil_c are quite similar. Flashpoint is a safety related characteristic, it defines the minimum temperature at ambient pressure at which vapor air mixture can be ignited in a closed space.

The result showed that Oil_a had the saponification value of 171 which was higher than that of Oil_b 164 and Oil_c 161. These values obtained was quite similar 174 that was reported by Acevedo *et al.* (2018) for waste frying oil. From the result, it was also observed that the values were so different from 192 that was reported by Eboibi *et al*. (2018) for jatropha oil. Saponification value is a measure of the average molecular weight of all the fatty acids present in the sample as triglycerides.

The iodine value results showed that Oila had the highest value 124, followed by Oil_b of 122 and Oil_c of 118. Iodine value measures the degree of unsaturation of an oil, fat or wax.

3.3 Physicochemical Analysis of Biodiesel

The result showed the percentage yield of the biodiesel to be 28%. The result is quite promising compared to the previous researches carried out in the past. The value of the percentage yield may be as a result of the catalyst NaOH used which is basic in nature.

The specific gravity was observed to give a value of 0.84, this value is still in line with the ASTM standard of 0.95max. the result was observed to be similar to 0.91 which was reported by Ebiobi *et al.* (2018). Specific gravity is related to the ability of an object to float in air or water.

The result obtained showed the value of viscosity as 2.95. viscosity is the measure of material resistance to flow, higher viscosity materials flows with great difficulty and a material with less viscosity flow more easily. Viscosity is important to biodiesels because it has impacts on the operation of some engine components such as fuel pump. The value of the viscosity was observed to be higher than 2.65 that was reported by Ebiobi *et al*. (2018), however it is within the specified range of the ASTM standard of 1.90 to 6.00.

The study of the acid value gave 0.502. acid value is a relative measure of rancidity as free fatty acids are normally formed during decomposition of triglycerides. From the result, the acid value was observed to be so different from 1.5 that was reported by Acevedo *et al,* (2018). A high acid value in biodiesel can lead to engine corrosion and deterioration of the diesel, however the observed acid value was seen to be in conferment with the ASTM standard of 0.5

The study indicates that the cetane number is 45.82. Cetane number is an indicator of the combustion speed of diesel fuel and compression needed for ignition. It plays a similar role for diesel as octane rating does for gasoline. From the result, it was observed that the cetane number is in line with the ASTM standard of 46-52. Fuels with lower cetane number have longer ignition delays, requiring more time for the fuel combustion process to be completed. Hence, higher speed diesel engine operates more effectively with higher cetane number.

The flashpoint was observed to give a value of 140. It was also observed that the result was lower than 176.25 which was reported by Acevedo *et al.* (2018). Also, the result is quite similar to 146 which was reported by Eboibi *et al*. (2018). The flashpoint of a diesel can change based on the air and pressure around the liquid. However, the result of the flashpoint is within the range of the ASTM standard which has a minimum of 130.

The cloud point gave a value of 5.07. the cloud point of a diesel fuel is the temperature below which wax forms giving the fuel a cloudy appearance. From the result, it was observed that the value gotten is lower than 8 that was reported by Eboibi *et al.* (2018). The result was also observed to be within the ASTM standard range of 4.80 to 5.30. this parameter is an important property of the fuel since the presence of solidified waxes can clog filters and negatively impact engine performances.

Table 1: Physicochemical Analysis of Sawdust Sample

Parameters	Values
Moisture content (%)	10.58 ± 0.47
pH	8.23 ± 0.31
Tap density	0.43 ± 0.06
Bulk density	0.32 ± 0.04
True density (g/cm^3)	1.36 ± 0.10
Compressibility index (%)	20.33 ± 1.37

Number of replicates = 3; Mean ± Standard Deviation

Table 2: Physicochemical Analysis of Sawdust Oil

Test	Oil_A	Oil_B	Oil_C
Percentage yield (%)	$13.20^a \pm 0.70$	$14.03^a \pm 0.61$	$15.57^b \pm 0.35$
pH	$7.30^a \pm 0.10$	$7.90^b \pm 0.10$	$8.30^c \pm 0.10$
Specific gravity	$0.91^a \pm 0.02$	$0.85^b \pm 0.05$	$0.80^b \pm 0.02$
Refractive Index	$1.37^a \pm 0.02$	$1.52^a \pm 0.12$	$1.49^a \pm 0.12$
Viscosity	$4.70^a \pm 0.15$	$4.50^a \pm 0.09$	$4.50^a \pm 0.10$
Flash point	$136^a \pm 4.00$	$135^a \pm 4.90$	$132^a \pm 3.80$
Saponification value (mg KOH/g)	$171^a \pm 6.00$	$164^a \pm 6.02$	$161^a \pm 6.42$
Iodine Value (mg I/g)	$124^a \pm 5.00$	$122^a \pm 2.60$	$118^a \pm 3.05$

Number of replicates = 3; Mean ± Standard Deviation; Mean with different superscript across rows are significantly different at ($P>0.05$)

Oil extracted using 0.1M NaOH as catalyst (Oil_{-A}), oil extracted using 0.2M NaOH as catalyst (Oil_{-B}), oil extracted using 0.3M NaOH as catalyst (Oil_{-C})

Table 3: Physicochemical Analysis of Biodiesel

Parameters	Experimental Values	ASTM Standard
Percentage yield (%)	28	
Specific Gravity	0.849	0.95 max
Viscosity	2.95	1.90 to 6.00
Acid value mg KOH/g	0.502	0.50
Cetane Number	45.82	46 to 52
Flashpoint (°C)	140	130 min
Cloud point (°C)	5.07	4.80 to 5.30
Water by distillation (%)	ND	0.5 max
Ash content (%)	ND	0.1 max

4. Conclusions

The result obtained from the physicochemical analyses of the saw dust showed that sawdust is potential feedstock for extraction of oil. The physicochemical properties of the produced biodiesel were analyzed for specific gravity (0.849), kinematic viscosity (2.9), acid value (0.502 mgKOH/g), cetane number (45.82), cloud point (5.07 ^{0}C), flash point (140^{0}C), water by distillation (not detected) and ash content (not detected).

From the results obtained in this study, the physicochemical properties of the produced biodiesel were within ASTM recommended values, indicating a quality fuel production. Thus, sawdust oil is an excellent feed stock for the production of biodiesel.

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