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Biodiesel production from new non-edible Allanblackia floribunda seed oil

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Abstract:** **Allanblackia floribunda oil, a by-product of pharmaceutical factory was investigated for the potential non-conventional and non-edible feedstock for preparation of biodiesel. Response surface methodology was applied to optimize the reaction conditions of the formation of methyl esters. Prediction using statistical model indicated that the maximum conversion yield would be 89.0% at the optimized reaction conditions, which included temperature of 64.1 ˚C, oil-to-methanol molar ratio of 1:10.5 and catalyst amount was 1.1%. The predicted yield corresponded with the mean value of 90.3 ± 0.9% (n=3). With the exception of oxidation stability and cold flow properties which could be improved easily by several effective means, the qualities of the cetane number, kinematic viscosity and the flash point of the biodiesel produced from Allanblackia floribunda oil at the optimum reaction conditions all met the relevant ASTM D 6751 and European EN 14214 biodiesel standards. The results indicate that Allanblackia floribunda oil could be used as a new potential non-edible feedstock for biodiesel production.

Key words: **Biodiesel, Allanblackia floribunda oil, tranesterification, Methyl esters, Response surface methodology.**

I. INTRODUCTION

Petroleum is one of the most important resources for power generation in the world. It is used in industries, transportation sector, production of chemicals etc. Due to the frequent changes in the price of crude petroleum and its products coupled with air pollution caused by the combustion of fossil fuels, attention has been drawn to need alternative fuels source [1]. Among the available alternative fuel sources, biodiesel (fatty acid methyl esters, FAMEs) is one of the possible alternatives that can be much preferred. This is as a result of its efficient biodegradability nature, non-toxic nature, inherent lubricity and relatively high flash point. It also reduces most of the regulated exhaust emissions [2]. Biodiesel can also be used without any modification in diesel engines, boilers or other combustion equipments [3]. Biodiesel has earlier on been developed using the edible feedstocks such as soybean, cannola, rapeseed, sunflower, palm oil etc. [4] Most of them are the high cost of commodity vegetable oils. The use of edible oils for biodiesel production has increased the problem of food versus fuel. According to Mustafa et al. [5] the non-food uses of edible oils are worsening the problem of food shortages and these consequently affects the economy. To help address the problem researchers over the years have been conducting research using some on-edible, non-conventional and low cost feedstocks such ascamelina [6], jatropha [7], roselle [8], moringa [9], okra [10] and kusum [11] to produce biodiesel.

The tallow tree (Allanblackia floribunda) is a woody dicotyledonous and underutilized plant belonging to the family Guttiferae and the genus Allanblackia. It is an evergreen plant that thrives well in wet places especially in the rainforest regions. The trees are widely distributed in certain parts of Africa, mostly in Sierra Leone to Cameroon and Gabon, Congo Brazzaville and Uganda. In Ghana it is found growing in the Western, Central, Ashanti and Eastern Regions in forest stands as well as on cocoa farms. (Irvine, 1961). Traditionally, the oil extracted from seeds has been used locally for cooking, preparing medicines and making soap at a subsistence level. It has recently been found that the oil could be used in the manufacturing of spreads (margarine), soap and beauty products. Several properties of this oil, for example high melting point and better food value among others, make it superior to alternatives like palm oil (Novella Partnership, 2008). While, the oil is a by-product in most industrial production and it has not yet been widely used because of its relatively uncompetitive usage in food. However, it provides a new potential non-edible feedstock for biodiesel production. For the purpose of full development and utilization of Allanblackia floribunda oil, this study was undertaken to optimize the reaction condition by response surface methodology (RSM) and evaluate the properties and application feasibility of the biodiesel obtained from Allanblackia floribunda oil.

II. MATERIALS AND METHODS

A. Materials

The crude Allanblackia floribunda oil was obtained from Rite Aid Pharmaceutical Co., Ltd (Ghana). All chemicals used in the experiments including methanol, potassium hydroxide, n-heptane, and tetradecane (internal standard for GC) were obtained from Rite Aid Reagent Co., Ltd. (Ghana) and were all of analytical reagent (AR) grade.

B. Extraction of oil

Allanblackia floribundaseeds were dried at 60 ºC for 10 h in an oven to remove excess moisture prior to the extraction process. The dried seeds were then weighed and ground into particles of 0.5–10 mm. The oil was extracted using soxhlet extractor with petroleum ether (60-90 ºC) as the solvent. The duration for each batch of extraction was 10 h. The volume of solvent per gram of seed was 10 ml. After extraction, the oil was obtained through rotary evaporator. The amount of the oil in the seeds was then calculated. The fatty acids composition was subsequently determined and identified using GC-MS.

C. Alkali-catalyzed transesterification

Methyl esters of *Allanblackia floribunda* oil were prepared by refluxing the oil at a preset temperature with a certain volume of methanol containing potassium hydroxide as catalyst for 2 h in a 250 mL three-neck reaction flask equipped with a condenser. After the reaction, two layers were formed in a separatory funnel. The layer consisted of methyl esters, methanol traces, residual catalyst, and some other impurities. After drawing off the lower layer of the glycerol, the product was purified by neutralizing with 10% of sulphuric acid. The product was then thoroughly washed with water. The methyl esters layer was then dried under reduced pressure at a temperature of 70 ˚C by a rotary evaporator.

D. Methyl esters analyses

The contents of methyl esters obtained using method 2.3, were determined by GC-MS. This was carried out on Agilent HP-6890 gas chromatograph (Agilent Technologies, Palo Alto, CA, USA) with a HP-5MS 5% phenylmethylsiloxane capillary column (30 m × 0.25 mm i.d., film thickness 0.25 µm; Restek, Bellefonte, PA). Helium was used as a carrier gas at a flow rate of 1.0 mL/min. Each sample (1 µL) was injected into the column at a split ratio of 14:1. The oven temperature ramp program was carried out using recommended method [16]. The identification of fatty acids was performed by comparing the obtained mass spectra with NIST05.LIB and NIST05s.LIB (National Institute of Standards and Technology) libraries data provided by the software (AMDIS-Chromatogram) of GC-MS system.

E. Yield determination

Biodiesel yields were determined by 7890A gas chromatograph (Agilent Technology Inc. USA) equipped with flame-ionization detector (FID) and HP-5 capillary column (30 m × 0.32 mm × 0.25 µm). Helium was used as the carrier gas. The oven temperature ramp program was carried out using the GC-MS method. Biodiesel yield was quantified using tetradecane as the internal standard. The analysis of biodiesel for each sample was carried out by dissolving 1 mL of the sample into 5 mL of *n*-hexane and injecting 0.5 µL into GC. The yield of the biodiesel was calculated from the content of methyl esters analyzed with GC using the following equation:

$$Biodiesel\ yield = \frac{w_{\text{tetradecane}} \times A_B \times f_{\text{tetradecane}}}{A_{\text{tetradecane}} \times w_s} \times 100\% \qquad (1)$$

Where $w_{\text{tetradecane}}$ is the weight of the internal standard, A_B is the peak area of methyl esters, $f_{\text{tetradecane}}$ is the response factor, $A_{\text{tetradecane}}$ is the peak area of the internal standard, and w_s is the weight of the sample.

Table 1 Factors and their levels for central composite design

Variables	Symbol	Coded factor levels				
		-2	-1	0	1	2
Reaction temperature (˚C)	X_1	44.18	50.00	60.00	70.00	76.82
Catalyst amount (% (w/w))	X_2	0.17	0.6	1	1.5	1.94
Oil/methanol molar ratio (N/A)	X_3	4.47	6	8	10	11.36

F. Experimental design and statistical analysis

In order to optimize the best combination of reaction variables, a three-variable and five-level central composite design (CCD) was adopted in this study. The three independent variables included the reaction temperature (X_1), catalyst amount (X_2), and oil to methanol molar ratio (X_3). The coded and uncoded levels of the independent variables are given in Table.1. The experimental design and result of the CCD were shown in Table 2.2.

Table 2. Central composite design, experimental and estimated data for 5-level-3-factors response surface analysis

Std	Run	Reaction temperature (˚C)	Catalyst amount (% (w/w))	Oil/methanol molar ratio (N/A)	Fatty acid methyl ester content (%)	
					Experimental	Estimated
1	20	-1	-1	-1	65.5	66.1
2	18	1	-1	-1	74.2	77.2
3	4	-1	1	-1	77.1	77.6
4	9	1	1	-1	81.8	84.9
5	5	-1	-1	1	76.7	75.5
6	17	1	-1	1	80.4	82.0
7	13	-1	1	1	81.8	80.9
8	2	1	1	1	82.1	83.6
9	6	-2	0	0	65.2	66.7
10	1	2	0	0	84.1	80.5
11	7	0	-2	0	68.5	67.4
12	10	0	2	0	81.4	80.4
13	16	0	0	-2	77.4	74.9
14	11	0	0	2	82.6	83.0
15	14	0	0	0	89.3	88.4
16	3	0	0	0	88.1	88.4
17	15	0	0	0	87.7	88.4
18	19	0	0	0	89.7	88.4
19	8	0	0	0	86.6	88.4
20	12	0	0	0	85.1	88.4

A mathematical model, describing the relationships between the predicted response variable (yield of biodiesel) and the reaction conditions in second-order equation was generated :

$$Y = \sum \lambda_0 + \sum_{i=1}^{3} \lambda_i X_i + \sum_{i=1}^{3} \lambda_{ii} X_i^2 + \sum_{i=1}^{2} \sum_{j=i+1}^{3} X_i X_j \quad (2)$$

Where Y is the predicted response (yield of the biodiesel), λ_0 is a constant, λ_i is the linear coefficient, λ_ii is the squared coefficient, and λ_ij is the interaction coefficient. $X_\mathrm{i}$and X_j are the independent variables. Design-Expert 7.1.3 Trial (State-Ease, Inc., Minneapolis MN, USA) was used for regression analysis to obtain the coefficients of the quadratic polynomial model. Analysis of variance (ANOVA) was used for the graphical analysis of the data in order to obtain the interaction of the process variables with the response. The quality fit of polynomial model equations was expressed with the coefficient of determination R^2, and its statistical significance checked using F-value at a probability (p). When the p values are less than 0.05, it is considered to be statistically significant. By keeping one variable each at the central level, 3-D and contour plots of two factors against oil yield were drawn.

G. Properties of biodiesel

The major properties of the synthesized methyl esters were determined according to the standard methods. The cetane number was determined using the standard ASTM D6890, whilst the flash point was determined with ASTM D93. The content of the water was calculated by using coulometric Karl Fisher titration instrument according to ASTM D6304. Acid value (expressed as mg KOH/g) was determined by ASTM D664-01. Oxidative stability at temperature of 110 ˚C was obtained by the standard EN 14112 using the Rancimat method. ASTM D130 was applied for copper corrosion and ASTM D445 for kinematic viscosity at temperature of 40 ˚C. Sulfur content was obtained using ASTM D4294. Other properties including pour point, cloud point, cold filter plugging point, density at 20 ˚C, ash content and glycerin content determined using PRC standards were GB/T3535, GB/T510, GB/T 2540, SH/T0248, GB/T508 and SH/T0796, respectively.

III. RESULTS AND DISCUSSION

A. Characterization of the crude Allanblackia floribunda oil

Table 3 shows the GC-MS results of fatty acid contents of crude oil sample. The overall content of unsaturated and saturated fatty acids was 83.9% and 16.1% w/w, respectively. It has been established that the contents of free fatty acid (FFA) and moisture in oils are significant factors that can affect alkali-catalyzed transesterification [17-19]. Research by Hayyan [20] indicated that the FFA content in the oil should be less than 1% prior to alkali-catalyzed transesterification. The oil used in this study had a FFA content of 0.9%, which was determined using the method of AOAC (Association of Official Analytical Chemists), 984.20. Hence this oil had a suitable characteristic to be used as a feedstock to produce biodiesel by a one-step process of alkali-catalyzed transesterification.

Table 3: Contents of Fatty acid of Allanblackia floribunda oil

Fatty acid[a]	Amount[b] (%)
C14:0 Myristic acid	0.14%
C16:0 Palmitic acid	7.76%
C18:0 Stearic acid	4.70%
C18:1 Oleic acid	20.56%
C18:2 Linoleic acid	62.69%
C20:0 Arachidic acid	1.99%
C20:1 Gadoleinic acid	0.65%
C22:0 Behenic acid	1.43%
C24:0 Tetracosanoic acid	0.09%

[a] Fatty acid was determined by GC-MS.

[b] Esters amount was determined by GC, using tetradecane as an internal standard.

B. Optimization of reaction conditions using response surface methodology

The corresponding result of RSM experiments based on different combination of reaction temperature (X_1), catalyst amount(X_2), and molar ratio of oil to methanol (X_3) were shown in table 2. The regression coefficients of the intercept, the linear, quadratic and the interaction terms of model were calculated using the least square technique, and the results were presented in Table 4. It could be seen that all the independent variables and quadratic terms exhibited significant effect ($p< 0.05$) on the production of biodiesel. However, the interaction terms were found not to be significant ($p> 0.05$). The predicted yield of biodiesel could be obtained by following equation:

$$Y = 87.40 + 3.47X_1 + 3.62X_2 + 2.03X_3 - 3.45X_1^2 - 3.37X_2^2 - 2.11X_3^2 - 0.96X_1X_2 - 1.14X_1X_3 - 1.51X_2X_3 \quad (3)$$

As shown using ANOVA results in Table 2.5, the regression model for the data was found to be highly significant with a coefficient of determination (R^2) as 0.9374. It was noted that a low lack of fit was 0.1023. This indicates that the model does indeed represent the actual relationships of reaction parameters, which are within the selected ranges (Table .4).

Table 4: Regression coefficients of the second-order polynomial model for the response variables

Factor	Estimated coefficients
constant	87.40
linear	
Reaction temperature (X_1, ˚C)	3.47
Catalyst amount (X_2,%(w/w))	3.26
Methanol/Oil ratio (X_3)	2.03
Quadratic	
Reaction temperature (X_1, ˚C)	-3.45
Catalyst amount (X_2,%(w/w))	-3.37
Methanol/Oil ratio (X_3)	-2.11
Interactions	
$X_1 \times X_2$	-0.96
$X_1 \times X_3$	-1.14
$X_2 \times X_3$	-1.51

The 3D response surface plots and the 2D contour plots were provided as graphical representations of the regression equation (Figs. 1-3) which provided the method to visualize the relationship between responses and experiment levels of each variable as well as the type of interactions between the two test variables.

Table 5 ANOVA for response surface quadratic model analysis of variance

Source	Squares	df	Square	Value	Prob > F	
Model	969.01	9	107.67	16.65	< 0.0001	significant
A	192.52	1	192.52	29.77	0.0003	
B	169.65	1	169.65	26.33	0.0004	
C	66.02	1	66.02	10.21	0.0096	

AB	7.41	1	7.41	1.15	0.3096	
AC	10.35	1	10.35	1.60	0.2345	
BC	18.30	1	18.30	2.83	0.1235	
A^2	299.26	1	299.26	46.27	< 0.0001	
B^2	286.39	1	286.39	44.28	< 0.0001	
C^2	112.20	1	112.20	17.35	0.0019	
Residual	64.68	10	6.47			
Lack of Fit	50.00	5	10.00	3.41	< 0.1023	not significant
Pure Error	14.67	5	2.93			
Cor Total	1033.69	19				
R^2	0.9397			Adj-R^2	0.8811	
C.V.%	3.17			PRESS	431.8	

Fig.1a and 1b showed the 3D response surface plot and the contour plot at varying catalyst quantities and the reaction temperature on *Allanblackia floribunda* biodiesel yield at a fixed oil-to-methanol molar ratio of 1:10. It was observed that biodiesel yields increased significantly at reaction temperature of 50.0 to 64.1 ˚C, but beyond 64.1 ˚C, the yield remained constant. At the same time, the yields also increased rapidly with the increase of catalyst amount of 0.7 to 1.1%, then decreased slightly from 1.1 to 1.3%. This is in line with findings by Piyanuch Nakpong et al. and Wang et al.. It could be deduced that, due to the addition of a high amount of alkaline catalyst, soap was formed and these subsequently increased the viscosity of the reactants, thereby reducing the methyl ester content.

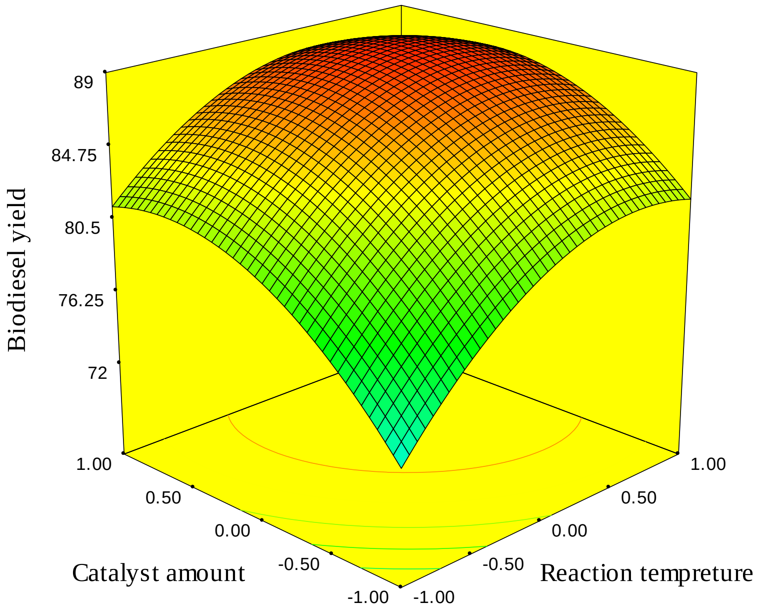

Fig.1: Response surface and contour plots for the effect of reaction temperature (X_1) and catalyst amount (X_2) on the biodiesel yield, oil-to-methanol molar ratio (X_3) kept in central points.

Fig. 2. represented the effects of oil-to-methanol molar ratio and reaction temperature on biodiesel yield at a constant catalyst amount of 1%. When the oil-to-methanol molar ratio increased to 1:10.5, the yield also increased to a point and remained constant. In the case of the oil yields, it first increased with the rise in reaction temperature of 50.0 ˚C to 64.1 ˚C, followed by a slight decline in the yield with further increase in the

temperature from 64.1 °C to 70.0 °C. The reason might be that the higher temperature accelerated the side saponification reaction of triglycerides [22].

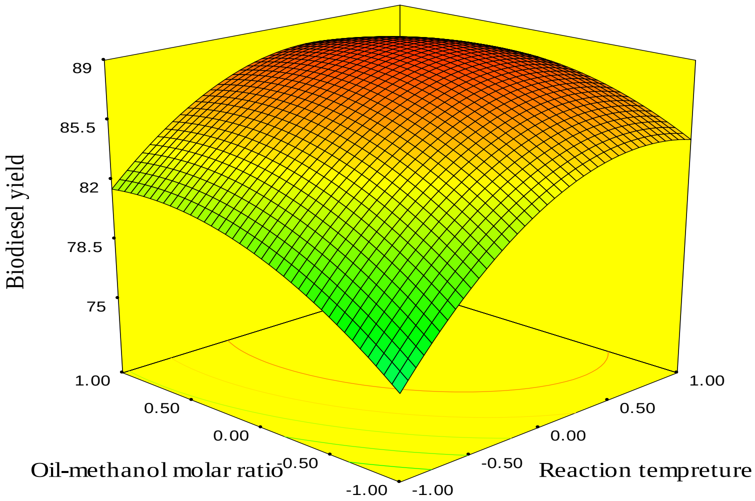

Fig.2: Response surface and contour plots for the effect of reaction temperature (X_1) and oil-to-methanol molar ratio (X_3) on the biodiesel yield, catalyst amount (X_2) kept in central points.

The 3D response surface plot and the contour plot in Fig.3, which indicate the biodiesel yield as a function of catalyst amount and oil-to-methanol molar ratio at a fixed temperature indicated that both the catalyst and molar ratio had a positive effect in most of the time. The maximum biodiesel yield was obtained at catalyst amount of 1.1% with molar ratio of 1:10.5. None of the two factors yielded a positive effect after the plateau. A dilution effect was the likely cause of the higher molar ratio decreased of the biodiesel yield. Umer Rashid et al. applied a ratio of 1:6 to obtain the maximum ester formation from rapeseed oil. A further increase in the molar ratio of methanol to oil also indicated very limited effect on rapeseed esters yield and a long time of subsequent separation stage.

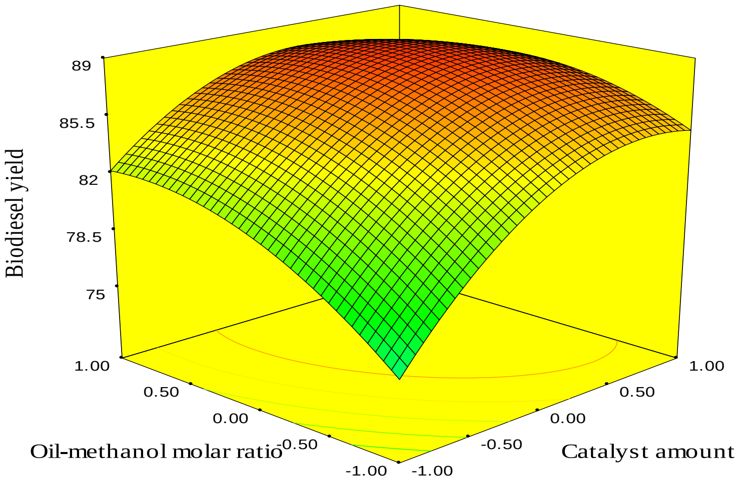

Fig 3: Response surface and contour plots for the effect of catalyst amount (X_2) and oil-to-methanol molar ratio (X_3) on the biodiesel oil yield, reaction temperature (X_1) kept in central points.

The optimal condition obtained with RSM at three-variable and five-level CCD include reaction temperature of 64.1 °C; catalyst amount of 1.1% and oil-to-methanol molar ratio of 1:10.5 with the predicted biodiesel of 88.9%. Additional experiment was carried out to validate the optimization result. The mean value of 90.3 ± 0.9% (n=3) obtained from the real experiments demonstrated the validity of the RSM model, because there was no significant ($p > 0.05$) differences between 89.0% and 90.3 ± 0.9% (n=3). The correlation between the real and the predicted results also confirmed that the response model was adequate to reflect the expected optimization.

C. Properties of the Allanblackia floribunda biodiesel

Since the quality of any proposed new biodiesel fuel is essential for the performance and emission characteristics of diesel engines, it is necessary that the *Allanblackia floribunda* biodiesel undergo testing with standard methods. The results of the study with standards are listed in table 2.6.

1. *Cetane number*

The cetane number is one of the most significant properties to specify the ignition quality of fuel for use in a diesel engine. This is related to the ignition delay time. A high cetane number implies better ignition properties which is associated with esters of saturated fatty acids such as palmitic acid (C16:0) and to mono-unsaturated compounds such as methyl esters of oleic acids (C18:1) [24]. As shown in Table 6, the cetane number for *Allanblackia floribunda* biodiesel was 51, which was within the international quality standards; minimum of 47 (American standard ASTM D 6751) or 51 (European standard EN 14214).

2. *Kinematic viscosity*

Kinematic viscosity is an important fuel property since it affects the operation of fuel injection equipment[25]. The results showed that alkali-catalyzed transesterification reduced the viscosity of the crude oil from mean value of 34.76 to 4.30 mm^2/s. This value is within the biodiesel standards of 1.9 - 6.0 mm^2/s in the American standard ASTM D6751 and 3.5 - 5.0 mm^2/s in the European standard EN 14214.

3. *Oxidative stability*

The oxidative stability of *Allanblackia floribunda* biodiesel was determined by the Rancimat method (EN 14112) which utilized 3 g of biodiesel per test. An induction period of 2.87 h was used for the study. This figure was close to the oxidative stability requirement of 3 h in ASTM D6751. This observation could be attributed to the relatively high methyl linoleate (C18:2) content of crude oil (Table 3), as the oxidative stability of methyl linoleate was found to be 0.94 h [26]. Adding antioxidants as one of the procedures used for many biodiesel fuels might increase the induction time to a value above the minimum times prescribed in biodiesel standards [27, 28].

4. *Cold flow properties*

The key cold flow properties for biodiesel fuel specifications include cloud points (CP), pour point (PP) and cold-filter plugging point (CFPP). The poor cold flow properties of many biodiesel fuels have been a technical reason impairing the more widespread of many biodiesel fuels [29]. The CP, PP and CFPP observed for *Allanblackia floribunda* biodiesel were 6 °C, 2 °C and 13 °C, respectively. These parameters were relatively higher than the conventional biodiesel from edible resource including rapeseed, sunflower, soybean etc but with the exception of peanuts biodiesel, which had a high CFPP of 16 °C[30]. This might be due to the fact that *Allanblackia floribunda* biodiesel was relatively rich in methyl esters of long carbon chain saturated fatty acids like behenic (C22:0) and lignoceric (C24:0) acid as well as peanut biodiesel. The longer the carbon chains in the biodiesel, the worse the low temperature properties [31]. Pérez et al. introduced a method of crystallization filtration to reduce the CFPP of peanut biodiesel from 17 °C to 8 °C[32]. Another effective method to improve its cold flow properties is to introduce ethanol, pour point depressants and commercial additives [33, 34]. As a result, the uncompetitive cold flow properties can be easily improved by several methods.

Table 6: Central composite design, experimental and estimated data for 5-level-3-factors response surface analysis

Std	Run	Reaction temperature (°C)	Catalyst amount (% (w/w))	Oil/methanol molar ratio (N/A)	Fatty acid methyl ester content (%)	
					Experimental	Estimated
1	20	-1	-1	-1	65.5	66.1
2	18	1	-1	-1	74.2	77.2
3	4	-1	1	-1	77.1	77.6
4	9	1	1	-1	81.8	84.9
5	5	-1	-1	1	76.7	75.5
6	17	1	-1	1	80.4	82.0
7	13	-1	1	1	81.8	80.9
8	2	1	1	1	82.1	83.6

9	6	-2	0	0	65.2	66.7
10	1	2	0	0	84.1	80.5
11	7	0	-2	0	68.5	67.4
12	10	0	2	0	81.4	80.4
13	16	0	0	-2	77.4	74.9
14	11	0	0	2	82.6	83.0
15	14	0	0	0	89.3	87.4
16	3	0	0	0	88.1	87.4
17	15	0	0	0	87.7	87.4
18	19	0	0	0	89.7	87.4
19	8	0	0	0	86.6	87.4
20	12	0	0	0	85.1	87.4

D. Other properties

The flash point (FP) of biodiesel is relatively higher than that of petroleum diesel which makes it safer for transportation. Accordingly, *Allanblackia floribunda* biodiesel displayed flash point of 152 ˚C, which was within the specifications of both standards (Table 6). Acid value, copper strip corrosion (3 h at 50 ˚C) and sulfur content (close to the limit in EN 14214) were also determined (Table 2). From the results of the study it could observed that all the properties of *Allanblackia floribunda* biodiesel were within ASTM D6751 specifications.

Table 7: Properties of Allanblackia floribunda biodiesel with comparison to biodiesel standards.

Fuel property	*Allanblackia floribunda* biodiesel	ASTM D6751	EN 14214
Cetane number	51	≥47	≥51
Kinematic viscosity(mm^2/s; 40 ˚C)	4.298	1.9-6.0	3.5-5.0
Oxidative stability (h)	2.87	≥3	≥6
Cloud point (˚C)	2		
Pour point (˚C)	6		
Cold filter plugging point (˚C)	13		
Flash point (˚C)	152	≥93	≥120
Sulfur content (%, w/w)	0.002	≤0.05	
Ash content (%, w/w)	0.018	≤0.02	≤0.02
Acid value (KOH mg/kg)	0.454	≤0.5	≤0.5
Copper strip corrosion (50 ˚C; 3 h)	1 a	≤No.3a	≤No.1a
Water (mg/kg)	400		
Density (20 ˚C)	865		860-900
Free glycerin (%, w/w)	0.01		≤0.020
Total glycerin (%, w/w)	0. 14		≤0.25

IV. CONCLUSION

This study revealed a new kind of biodiesel which could be produced from Allanblackia floribunda oil as by-product from pharmaceutical factory through alkali-catalyzed transesterification. The optimum conditions for producing this biodiesel (Allanblackia floribunda oil) included an oil-to-methanol molar ratio of 1:10.5, a catalyst amount of 1.1%, and a reaction temperature of 64.1 ˚C. The predicted fatty acid methyl ester content was approximately 89.0% which correspond with the mean value of 90.3 ± 0.9% (n=3). The quality of biodiesel produced from Allanblackia floribunda oil under optimal conditions also met the standards for biodiesel quality without cold flow properties and oxidative stability. However, the two properties (cold flow properties and oxidative stability) can be improved easily by several effective means. It can therefore be concluded that Allanblackia floribunda oil could be used as a new potential non-edible feedstock for biodiesel production.

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