



### Article Info

Received: 21<sup>st</sup> April 2020

Revised: 16<sup>th</sup> June 2020

Accepted: 18<sup>th</sup> June 2020

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Cite this: *CaJoST*, 2020, 2, 111-119

## Process Optimization of Biodiesel Production from *Parinari macrophylla* Seed Oil using CaO/Al<sub>2</sub>O<sub>3</sub> and MgO/Al<sub>2</sub>O<sub>3</sub> Catalysts

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An Increase in environmental pollution due to exhaust emissions coupled with depletion of fossil fuel leads to search for alternative green sources of energy. Biomass have been suggested as alternative energy sources and the use of biodiesel as promising potential grows rapidly due to its great contribution to the environment and to its role as a strategically source of renewable energy in substitution to diesel oil and other petroleum-based fuels. The production of biodiesel from *Parinari macrophylla* seeds oil using two catalysts; CaO/Al<sub>2</sub>O<sub>3</sub> and MgO/Al<sub>2</sub>O<sub>3</sub> for optimization studies was investigated. The catalysts were prepared using wet impregnation method and characterized using FT-IR analysis. The optimization process was designed using Box-Benken, a response surface methodology. An optimum biodiesel yield of 93.0% was obtained using CaO/Al<sub>2</sub>O<sub>3</sub> at a temperature of 60°C, 120 min reaction time, 9:1 methanol to oil ratio and 1.0wt% catalyst loading while MgO/Al<sub>2</sub>O<sub>3</sub> catalyst give an optimum yield of 90.24% at a temperature of 50°C, 150 minute reaction time, 3:1 methanol to oil ratio and 1.0wt% catalyst loading respectively. Methyl esters composition indicated the presence of 9-octadecanoic (z) methyl ester (23.79%), 11-octadecanoic acid (z) methyl ester (13.21%), Palmitic acid (hexadecanoic) (34.12%), Oleic (Octadecenoic) (13.42%) and Octadecanoic acid (11.00%) as dominant fatty acids methyl esters. The observed fuel properties of the biodiesel produced were in conformity with ASTM specification.

**Keywords:** Optimization, *Parinari macrophylla* seed oil, Heterogeneous catalysts and Biodiesel.

### 1. Introduction

The depletion of world crude oil reserves and increased deteriorating climate conditions associated to the use of fossil fuels have stimulated the search for an alternative and efficient fuel by many researchers in recent years. One of the most promising alternative fuels is biodiesel, which has attracted attention worldwide. This is due to its overwhelming benefits over the conventional petrodiesel. It is renewable, biodegradable, and non-toxic, with high flash point and good reduction in greenhouse emissions profile (Atadashi *et al.*, 2011).

Biodiesel is the free fatty acid methyl esters known as FAME, derived from fat and oil sources. There are various processes that have been adopted in the production of biodiesel from vegetable oils and animal fats among which transesterification is the key and foremost important process to produce the cleaner and environmentally safe fuel. However, when it is compared to petroleum diesel, biodiesel production costs are still relatively high. Some

attempts have been conducted to reduce the production cost of biodiesel, one of them is by using heterogeneous catalysts. Commonly, biodiesel production uses homogeneous base or acid catalysts such as NaOH, KOH, and H<sub>2</sub>SO<sub>4</sub> which have several setbacks such as catalyst separation and products purification (Liu *et al.*, 2007)

The used of heterogeneous base catalysts recently have attracted researchers interest in biodiesel production as it overcomes the separation, purification, corrosion and environmental problems. Thus simplifies the process and consequently lower the production cost. Moreover, it can tolerate the high FFA and water contents of the feedstock, and it is recyclable and reusable (Abdallah *et al.*, 2017). Heterogeneous catalysts were introduced to overcome problems associated with homogeneous catalysts. Heterogeneous catalysts are in different phase with the product, therefore relatively easier for product purification. The use of these catalysts will therefore reduce

the production cost. In addition, there are reusable and environmentally friendly (Pasupulety *et al.*, 2013).

The problem of using heterogeneous catalysts relies on the diffusion mechanism due to three phases of reaction mixture (Oil-Methanol-Catalyst). Moreover, heterogeneous catalysts have relatively low activity, which leads to higher catalyst loading; longer reaction time (Obidiah *et al.*, 2012). This problem can be overcome by using promoter or support catalyst which can increase the catalyst surface area, life time and thermal stability. In comparison to the unsupported catalyst the composite catalyst has a larger specific surface area, more active sites and pores. This facilitates the attachment of large triglyceride molecules with the active catalyst species (Pasupulety *et al.*, 2013). Although heterogeneous catalysts have gained special attention for biodiesel production, because of their high catalytic efficiency, large surface area, high resistance to saponification and good rigidity (Hu *et al.*, 2011). The production of biodiesel using combined metal oxides (as catalyst) is very limited.

This study aims at optimizing the transesterification process for biodiesel production from *Parinari macrophylla* seed (Locally called Gawasa in Hausa) oil using CaO/Al<sub>2</sub>O<sub>3</sub> and MgO/Al<sub>2</sub>O<sub>3</sub> as solid base catalysts. The experiment was designed using Box-Behnken design on Design Expert version 6.0.6. The fuel properties of the biodiesel produced at optimum conditions were determined.

## 2. Materials and Methods

### 2.1 Materials

Fresh fruits of *Parinari macrophylla* were collected from sabon garin dole village in Goronyo local government area of Sokoto State, Nigeria. The oil from *Parinari macrophylla* seeds was extracted using Soxhlet extraction method with n-hexane as solvent. All the chemical reagents used in this study were of analytical grade. Ca(OH)<sub>2</sub>, Mg(NO)<sub>3</sub> and Al<sub>2</sub>O<sub>3</sub> were commercially available.

### 2.2 Catalyst Preparation and Characterization

80g of aluminium oxide was accurately weighed and taken into a 500cm<sup>3</sup> beaker. 100cm<sup>3</sup> of distilled water was measured and transferred into the beaker. 20g of calcium hydroxide and magnesium nitrate powder each were weighed and added separately into the beaker. The

mixture was placed on a hot plate equipped with magnetic stirrer and heated at a temperature of 50°C for 2hrs. It was later transferred to the crucibles and taken to the oven and dried at a temperature of 105°C for 2hrs. it was later removed from the oven and taken to the muffle furnace and calcined at 600°C for 2hrs (Asri *et al.*, 2012). Functional groups were identified in the prepared catalysts using FTIR analysis and IR spectra were recorded in the range 4000-650cm<sup>-1</sup> and 950-400cm<sup>-1</sup> using Carry360 model spectrophotometer. The sample was mixed with alkali halide, potassium bromide then compressed into a thin transparent pellet using hydraulic press and placed in a standard sample compartment of the spectrometer and spectral data was obtained.

### 2.3 Determination of Physicochemical Properties of Biodiesel

The physicochemical properties of the biodiesel produced were tested according to ASTM standard. The properties studied were specific gravity using (ASTM D1298), kinematic viscosity at 40°C (ASTM D445), acid value (ASTM D664), flash point (ASTM D98), cloud point (ASTM D6371), ash content (ASTM D874) while the cetane number were determined using the equation 1. (Rahma *et al.*, 2014):

Where, SV is saponification value, IV is iodine value of the biodiesel.

$$CN = 46.3 + \left( \frac{5458}{SV} \right) - (0.225 \times IV) \dots \dots \dots 1$$

Other physicochemical properties such as acid value, saponification value and iodine value were determined by titrimetric method according to AOAC (2000).

### 2.4 Experimental Design

The biodiesel synthesis was developed and optimized using response surface methodology (RSM) provided by Design Expert software version 6.0.6 (Stat Ease Inc., Minneapolis, MN 55413). A standard RSM design tool known as Box-Behnken Design (BBD) was applied to study the optimization process. The effect of four independent parameters; reaction time (120 to 180 min.), methanol to oil molar ratio (3:1 to 9:1), reaction temperature (50 to 70°C) and catalyst loading (0.5 to 1.5wt.%) on biodiesel yield were study. The response chosen was fatty acid methyl ester (biodiesel) yield. The experiments were run at random in order to minimize errors from the systematic trends in the variables. Table 1, list the level of the independent parameters investigated.

**Table 1.** Independent parameters and their levels used for the response surface design

Independent parameters	Low level	High level
Time (min)	120	180
Catalyst (wt%)	0.5	1.5
MeOH/Oil ratio	3:1	9:1
Temperature (°C)	50	70

## 2.5 Transesterification of the oil using CaO/Al<sub>2</sub>O<sub>3</sub> and MgO/Al<sub>2</sub>O<sub>3</sub>

A required amount of raw *Parinari macrophylla* oil was weighed and poured into two separate conical flasks (250ml) labeled A and B respectively. Proper proportion of methanol to oil ratio (i.e. 3:1, 6:1, 9:1) were measured and required catalyst concentration were weighed and added. The mixture was placed in a water bath and heated at various level selected for optimization process as stipulated in the design matrix. After the transesterification reaction, the mixture was transferred into the centrifuging machine and the catalyst was separated by centrifuging at 1500 r.p.m for 10 minute. The mixture were cooled at room temperature and transferred into the separating funnel, to allow the glycerol to settle down overnight. The mixture was then washed with distilled water (10cm<sup>3</sup>) and n-hexane (10cm<sup>3</sup>) were added to enhance the separation into an upper phase (Biodiesel) and lower phase (glycerol). The settled glycerol was discarded and the biodiesel was collected. The % yield was obtained using Equation 2:

$$\% \text{Yield} = \frac{\text{Weight of biodiesel produced}}{\text{Weight of the oil}} \times 100 \dots \dots \dots 2$$

## 2.6 Methyl Ester Purification and Analysis

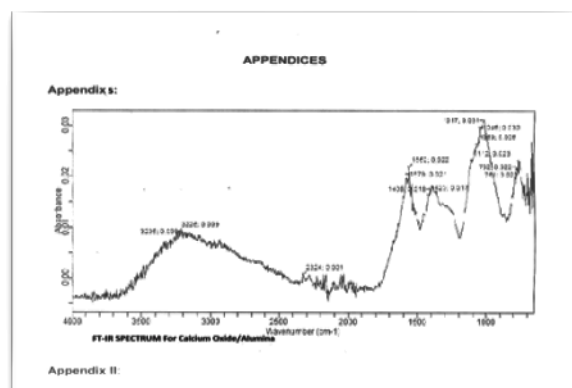
The biodiesel was mixed with distilled water and agitated gently to avoid formation of emulsion, then slowly percolating droplets of water through the ester (Atadashi *et al.*, 2011). The process was repeated until colourless wash water was obtained, indicating complete removal of impurities. The fatty acid methyl esters composition was determined using GC-MS as reported by Vietra *et al.* (2006). The result of the fatty acids methyl esters profile of the biodiesel produced using CaO/Al<sub>2</sub>O<sub>3</sub> was presented in Table 2.

**Table 2.** Fatty Acid Methyl Esters Composition of the Biodiesel

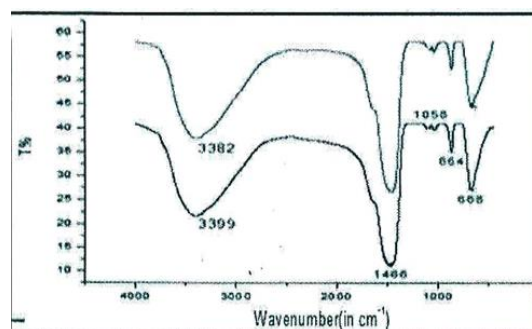
FAMES	% Composition
9-Octadecenoic acid (z) methyl ester	23.79
Hexadecanoic acid methyl ester	34.12
11-octadecenoic (z) methyl ester	13.21
Oleic acid	13.42
Octadecanoic acid methyl ester	11.00

## 3. Results and Discussion

### 3.1 Catalyst Characterization

**Figure 1.** FT-IR Spectra CaO/Al<sub>2</sub>O<sub>3</sub> Catalyst

The FT-IR spectra of CaO/Al<sub>2</sub>O<sub>3</sub> (fig.1) showed a broad absorption peak of CaO at a range of 900cm<sup>-1</sup>-800cm<sup>-1</sup>. The absorption peaks at 1500cm<sup>-1</sup> is attributed to OH stretching vibration mode of water hysiosorbed on the surface of CaO. A series of broad intense peaks belonging to the amorphous Al<sub>2</sub>O<sub>3</sub> dominate over the low wave number region of the Infrared spectrum from 1000-500cm<sup>-1</sup>.

**Figure 2.** FT-IR Spectra of MgO/Al<sub>2</sub>O<sub>3</sub> Catalyst

FTIR spectra of MgO/Al<sub>2</sub>O<sub>3</sub> calcined at 600°C is shown in fig.2, a broad band between 3500cm<sup>-1</sup> - 3330cm<sup>-1</sup> and that between 1700cm<sup>-1</sup> – 1400cm<sup>-1</sup> could be attributed to stretching mode vibration of OH group. The peaks at 1058cm<sup>-1</sup> was due to Al-O absorption, whereas peaks at 864cm<sup>-1</sup> and 668cm<sup>-1</sup> were attributed to Mg-O vibration mode of MgO (Li *et.al*, 2004).

### 3.2 Optimization of the Biodiesel Yield (using CaO/Al<sub>2</sub>O<sub>3</sub>)

The % yield of biodiesel obtained from the transesterification reaction using CaO/Al<sub>2</sub>O<sub>3</sub> as catalyst vary within a minimum and maximum yields of 69.60 and 93.00 % from the 29 Experimental runs as shown in (Table 3).

The analysis of variance (ANOVA) which was carried out to determine the significance and

fitness of the quadratic model as well as the effect of significant individual terms and their interaction on the yield were presented in (Table 3). The values of 'Prop > F' less than 0.05 indicated that the model terms are significant. In this case the significant model terms are A, C<sup>2</sup>, D<sup>2</sup>, AC and BC. The lack of fit value of 1.68 indicates that lack of fit is not significant relative to pure error. Non-significant lack of fit is most desirable. The value of regression coefficient (R<sup>2</sup>) for the model as shown in Table 4, is 0.8780 which means the model explains 87.80 % of the

variation in the experimental data. A low value of coefficient of the variation (C.V. %) of 3.65, indicated a high degree of precision and good deal of reliability of the model. The equation 3 shows the robust model equations in terms of actual factors where A, is reaction temperature, B is catalyst Conc., C is methanol/oil ratio and D is the reaction time respectively.

$$\% \text{ Yield} = +81.16+6.36A+1.30B+1.51C-0.67D+0.31+2.79C^2+3.80D^2-5.42AC+4.43BC \dots \dots \dots 3$$

**Table 3.** Experimental design and Biodiesel Yield using CaO/Al<sub>2</sub>O<sub>3</sub> Catalyst

Std	Run	Temp(°C)	Catalyst Conc. (%)	MeOH/Oil ratio	Time (min)	Yield (%)	
						Actual	Predicted
1	1	50.00	0.50	6:00	150	69.6	72.54
17	2	50.00	1.00	3:00	150	68	70.98
21	3	60.00	0.50	6:00	120	80.2	83.68
25	4	60.00	1.00	6:00	150	81.3	79.95
23	5	60.00	0.50	6:00	180	81.6	80.08
15	6	60.00	0.50	9:00	150	82.1	87.86
3	7	50.00	1.50	6:00	150	77.7	78.4
14	8	60.00	1.50	3:00	150	79.1	79.67
11	9	50.00	1.00	6:00	180	82.2	78.28
8	10	60.00	1.00	9:00	180	85.9	84.39
20	11	70.00	1.00	9:00	150	86.9	86.71
19	12	50.00	1.00	9:00	150	83.6	84.84
24	13	60.00	1.50	6:00	180	84.5	84.95
28	14	60.00	1.00	6:00	150	82.8	78.28
12	15	70.00	1.00	6:00	180	89.6	90.95
22	16	60.00	1.50	6:00	120	87.1	88.28
29	17	60.00	1.00	6:00	150	84.1	81.16
5	18	60.00	1.00	3:00	120	85.9	86.07
13	19	60.00	0.50	3:00	150	88.7	85.92
2	20	70.00	0.50	6:00	150	89.4	88.51
26	21	60.00	1.00	6:00	150	81.2	79.95
9	22	50.00	1.00	6:00	120	83.5	79.56
27	23	60.00	1.00	6:00	150	77.5	81.16
16	24	60.00	1.50	9:00	150	90.2	91.54
6	25	60.00	1.00	9:00	120	93	94.54
10	26	70.00	1.00	6:00	120	91	87.86
18	27	70.00	1.00	3:00	150	92	92.46
7	28	60.00	1.00	3:00	180	88.9	88.11
4	29	70.00	1.50	6:00	150	91	86.71

**Table 4.** Coefficient of Regression Analysis for Biodiesel Yield

Regression	Value
R square	0.8780
Adjusted R square	0.7560
Predicted R square	0.3958
Coefficient of Variance	3.65

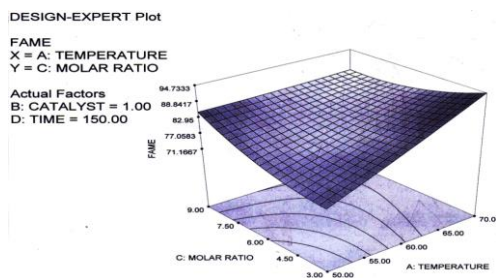
**Table 5:** Result of ANOVA for Biodiesel Yield using CaO/Al<sub>2</sub>O<sub>3</sub> Catalyst

Source	Sum of squares	df	Mean squares	F value	Prop > F
<b>Model</b>	916.14	14	65.44	7.20	0.0004
<b>A</b>	485.14	1	485.14	53.35	<0.0001
<b>B</b>	27.00	1	27.00	2.97	0.1069
<b>C</b>	27.30	1	27.30	3.00	0.1051
<b>D</b>	5.33	1	5.33	0.59	0.4565
<b>A<sup>2</sup></b>	0.59	1	0.59	0.065	0.8026
<b>B<sup>2</sup></b>	0.36	1	0.36	0.040	0.8450
<b>C<sup>2</sup></b>	50.01	1	50.01	5.50	0.0343
<b>D<sup>2</sup></b>	93.13	1	93.13	10.24	0.0343
<b>AB</b>	10.56	1	10.56	1.16	0.0064
<b>AC</b>	117.72	1	117.72	12.95	0.0029
<b>AD</b>	2.500E-003	1	2.500E-003	2.749.E-004	0.9870
<b>BC</b>	78.32	1	78.32	8.61	0.0109
<b>BD</b>	4.00	1	4.00	0.4	0.5180
<b>CD</b>	25.50	1	25.50	2.80	0.1162
<b>Residual</b>	127.31	14	9.09		
<b>Lack of Fit</b>	102.81	10	10.28	1.68	0.3262
<b>Pure Error</b>	24.51	4	6.13		
<b>Cor Total</b>	1043.45	28			

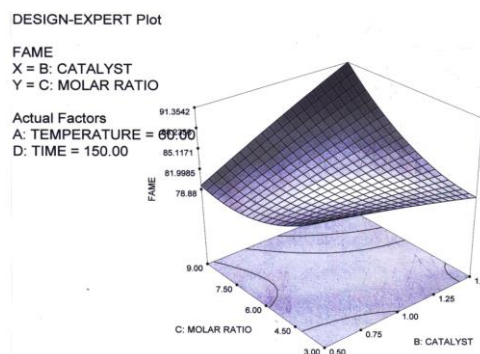
### 3.3 Effect of Transesterification Variable on Biodiesel Yield (using CaO/Al<sub>2</sub>O<sub>3</sub> catalyst)

The interactive effects of the process variables on the transesterification efficiency were studied by plotting 3D surface curves against any two independent variables, while keeping the other variables at their central level. The response surface curves were plotted to understand the interaction of the variables and to determine the optimum level of each variable for maximum response.

Figure 3, shows the effect of methanol to oil ratio and temperature on the biodiesel yield while keeping catalyst loading and reaction time constant at 1.0 w% and 150 min respectively. As evident from the figure, biodiesel yield increases as temperature and methanol to oil ratio increases. An optimum yield of 71% was obtained at a temperature of 63°C and 9:1 methanol to oil ratio. This observation agreed with that of Pradhan *et al.* (2012) who reported that both temperature and methanol to oil ratio had a significant interaction effect on biodiesel yield, but the temperature above boiling point of methanol (65°C) should be avoided.



**Figure 3.** Interactive effect between temperature and methanol to oil ratio on Biodiesel Yield



**Figure 4.** Interactive effect between catalyst loading and methanol to oil ratio on Biodiesel Yield

Figure 4, shows interaction effect of methanol to oil ratio and catalyst loading on biodiesel yield when temperature and reaction time are held constant at 60°C and 150 min. The Interaction effect between methanol to oil ratio and catalyst loading has synergistic effect on biodiesel yield as shown in equation 3. From the figure, it can be observed that biodiesel yield decreases with increase in catalyst concentration and methanol/oil ratio. The decrease in the yield at high catalyst concentration and methanol to oil ratio may be attributed to mass transfer resistance between the reactants, caused by high viscous reaction mixture at high catalyst concentration. Silva *et al.*, (2011) reported that methyl ester yield increases with low catalyst concentration.

### 3.4 Optimization of Biodiesel Yield (using MgO/Al<sub>2</sub>O<sub>3</sub> catalyst)

The percentage yield of the biodiesel produced using MgO/Al<sub>2</sub>O<sub>3</sub> as catalyst is presented in Table 6. The experimental run 2 gave the highest yield of 90.24%.

The result of analysis of variance (ANOVA) of biodiesel yield in Table 6 shows

that B (catalyst concentration) is the only significant linear term (p-value = 0.0024). Two interaction terms; AB (Temperature & Catalyst conc.) and AC (Temperature & methanol to oil ratio) were also statistically significant (p-value < 0.05). The lack of fit with F-value of 0.48 implies that lack of fit is not significant relative to pure error. The value of regression coefficient,  $R^2$  of 0.6251 as shown in (Table 7) indicated that only

about 63% of the experimental data is described by the model. The predicted  $R^2$  of 0.0711 is not as closed to the adjusted  $R^2$  as one might expect this could occur due noise. The insignificance of some of the terms investigated as observed in Table 8, could be attributed to experimental error involved compared to the effect of the variables investigated (Aminu *et al.*, 2015). After eliminating the statistically insignificant terms the regression model equation was reduced to equation.4:

**Table 6.** Experimental design and Biodiesel Yield using MgO/Al<sub>2</sub>O<sub>3</sub> Catalyst

Std	Run	Temp (°C)	Catalyst Conc.	MeOH/Oil	Time (min)	%Yield	
						Actual	Predicted
1	1	50	0.5	6:00	150	89.62	90.98
17	2	50	1	3:00	150	90.24	84.85
21	3	60	0.5	6:00	120	89.04	85.55
25	4	60	1	6:00	150	86.63	80.34
23	5	60	0.5	6:00	180	84.1	83.94
15	6	60	0.5	9:00	150	85.43	87.18
3	7	50	1.5	6:00	150	66.07	73.29
14	8	60	1.5	3:00	150	76.3	73.89
11	9	50	1	6:00	180	83	80.92
8	10	60	1	9:00	180	86	87.3
20	11	70	1	9:00	150	86.21	88.38
19	12	50	1	9:00	150	84	80.5
24	13	60	1.5	6:00	180	77	75.99
28	14	60	1	6:00	150	73	80.4
12	15	70	1	6:00	180	84	90.98
22	16	60	1.5	6:00	120	81	76.66
29	17	60	1	6:00	150	82	80.34
5	18	60	1	3:00	120	81	83.57
13	19	60	0.5	3:00	150	80.78	82.02
2	20	70	0.5	6:00	150	85	80.73
26	21	60	1:00	6:00	150	86.1	87.51
9	22	50	1	6:00	120	82.34	84.73
27	23	60	1	6:00	150	78.55	80.34
16	24	60	1.5	9:00	150	80.37	78.47
6	25	60	1	9:00	120	79.56	82.5
10	26	70	1	6:00	120	78	80
18	27	70	1	3:00	150	74	73.65
7	28	60	1	3:00	180	70	74.91
4	29	70	1.5	6:00	150	80	75.12

**Table 7: Coefficient of Regression Analysis for Biodiesel Yield**

Regression	Value
R square	0.6251
Adjusted R square	0.4168
Predicted R square	0.71
Coefficient of Variance	5.36

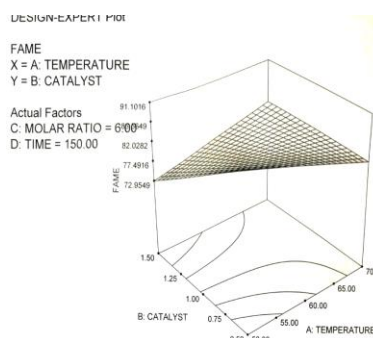
**Table 8: Result of ANOVA for Biodiesel Yield using MgO/Al<sub>2</sub>O<sub>3</sub> Catalyst**

Source	Sum of squares	df	Mean squares	F value	Prop > F
<b>Model</b>	571.33	10	57.13	3	0.0205
<b>A</b>	5.41	1	5.41	0.28	0.6004
<b>B</b>	236.12	1	126.12	12.4	0.0024
<b>C</b>	71.3	1	71.3	3.74	0.0688
<b>D</b>	3.9	1	3.9	0.2	0.6563
<b>AB</b>	86.03	1	86.03	4.52	0.0476
<b>AC</b>	85.1	1	85.1	4.47	0.0487
<b>AD</b>	7.13	1	7.13	0.37	0.5483
<b>BC</b>	0.084	1	0.084	4.42E-03	0.9477
<b>BD</b>	0.22	1	0.22	0.012	0.9154
<b>CD</b>	76.04	1	76.04	3.99	0.061
<b>Residual</b>	342.71	18	19.04		
<b>Lack of Fit</b>	218.38	14	15.31		
<b>Pure Error</b>	128.38	4	32.1		
<b>Cor Total</b>	914.08	28			

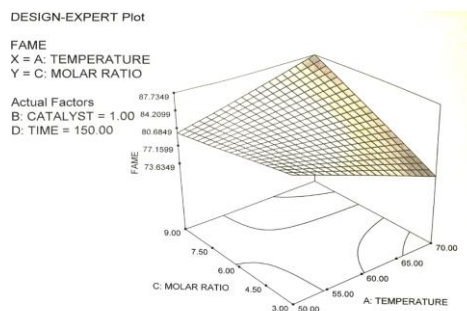
**3.5 Effect of Transesterification Variable on Biodiesel Yield (using MgO/Al<sub>2</sub>O<sub>3</sub> catalyst)**

The interaction effect of temperature and catalyst loading on biodiesel yield (when reaction time and methanol/oil ratio were kept constant at their central point) is shown in (fig.5). High biodiesel yield was obtained at low temperature and catalyst loading. The low yield at high temperature and catalyst loading may be due increase in bubbles in the reaction mixture which leads to turbulence and high mass transfer resistance. Furthermore, at higher temperature there will be increase in vaporization of methanol which lead to decrease in the availability of liquid methanol in the reaction mixture. Thus, leading to decrease in the reaction rate. However, high catalyst loading at high reaction temperature favors saponification of the triglycerides (Vicente *et al.*, 2007)

$$\% \text{ Yield} = +81.09 - 0.67A - 4.01B + 2.44C + 4.64AB + 4.61AC \dots \dots \dots 4$$



**Figure 5.** Interactive effect between Catalyst conc and Temperature on Biodiesel Yield



**Figure 6.** Interactive effect between MeOH/Oil ratio and Temperature on Biodiesel Yield

Fig. 6 shows a response surface plot for the interactive effect of temperature and methanol to oil ratio. The surface plot indicated that the methyl esters yield was high at low temperature and methanol/oil ratio. The yield then declined at a temperature above 50°C. The overall biodiesel yield decreased significantly to 73 % when the temperature reached 70°C. The optimum methanol to oil ratio was found to be 3:1, above this ratio the biodiesel yield starts to decline.

### 3.7 Physicochemical Properties of *Parinari macrophylla* Seed oil and its Biodiesel

Physicochemical properties are parameters that give vital information of the fuel as well as its possible applications. These properties include acid value, saponification value, iodine value, peroxide value, flash point, cloud point etc. The results of some of the physicochemical properties of the oil and its methyl esters produced using CaO/Al<sub>2</sub>O<sub>3</sub> catalyst was presented in Table 9. The properties of the biodiesel were compared with standard provided by ASTM. It can be seen from the table that all the selected physicochemical properties of the biodiesel determined were within the ASTM specification.

**Table 9:** Physicochemical Properties of *Parinari macrophylla* Seed oil and its Biodiesel

Properties	GBP oil	GBP Biodiesel	ASTM
Acid value	0.50±0.01	0.42±0.01	0.50 max
Iodine value	87±0.00	76±0.00	120 max
Saponification value	97±0.01	-	-
Kinematic viscosity	41.17±1.12	4.47±0.00	3.5-5.0
Flash point	-	138±0.02	130 max
Pour point	-	7±0.00	-15-10
Cloud point	-	3±0.00	-3-12
Centane number	-	56	65 max
Specific gravity	0.94±0.10	0.88±0.00	0.8-9.0
Ash content	-	0.03	0.05 max

GBP = Ginger bread Plum (*Parinari macrophylla*)

## 4. Conclusion

In this work, a study of optimization process for transesterification of Ginger bread Plum (*Parinari macrophylla*) seeds oil was carried out using CaO/Al<sub>2</sub>O<sub>3</sub> and MgO/Al<sub>2</sub>O<sub>3</sub> as solid base catalyst. Both CaO/Al<sub>2</sub>O<sub>3</sub> and MgO/Al<sub>2</sub>O<sub>3</sub> were observed to catalyze the transesterification process. However, CaO/Al<sub>2</sub>O<sub>3</sub> was observed to be more effective within the range of the parameters studied. The Optimal conditions were discovered to be 60°C temperature, 120 min reaction time, 1.00 wt% catalyst loading and 9:1 methanol to oil ratio. The physicochemical properties of the biodiesel produced using the catalyst were found to meet ASTM specifications for biodiesel.

## Acknowledgement

The Authors wish to acknowledge the Department of Pure and Applied Chemistry Usumanu Danfodiyo University, Sokoto for the full support in the conduct of the study.

## Conflict of interest

The authors declare no conflict of interest.

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