PROCESS OPTIMIZATION OF BIODIESEL PRODUCTION FROM CRUDE COCONUT SEEDS OIL USING $\text{CaO}/\text{Al}_2\text{O}_3$ AS HETEROGENEOUS CATALYST

Jamilu Usman*

Department of Chemistry, Faculty of Science,
Sokoto State University, Nigeria
Jamiluusman2020@gmail.com

Bashar Hadi Abdullahi

Department of Chemistry
Shehu Shagari College of Education, Sokoto, Nigeria
alkanci123@gmail.com

Buhari Idris

Department of Chemistry,
Ibrahim Badamasi Babangida University, Lapai, Nigeria
Buhariidris2017@gmail.com

Umar Musa Tanko

Department of Chemistry
Ibrahim Badamasi Babangida University, Lapai, Nigeria
Tankoum1@gmail.com

Bashar Usman

Department of Chemistry, Faculty of Science,
Sokoto State University, Nigeria
bashroad56@gmail.com

Jamila Baba Ali

Department of Polymer and Textile Engineering
Ahmadu Bello University, P.M.B 1044 Samaru, Zaria, Kaduna State, Nigeria.
jbabaali@abu.edu.ng

Kasimu Abubakar

Department of Chemistry, Faculty of Science,
Sokoto State University, Nigeria
katambuwal@gmail.com

***Corresponding author's Email:** jamiluusman2020@gmail.com

Abstract

Biodiesel is another promising form of biofuel derived from vegetable oil or animal fats through transesterification with methanol. Among the most frequently used method of biodiesel, base catalyzed transesterification stand out to be the best due to its economical process. Currently, formulation of abundant heterogeneous catalysts is in place which is reportedly to be effective than the catalysts formulated homogeneously. $\text{CaO}/\text{Al}_2\text{O}_3$ was synthesized using incipient wetness impregnation method. The biodiesel was processed and optimised using Box-behnken response surface methodology (RSM) design using MINITAP-17 statistical software. Reaction temperature, reaction time, catalyst concentration, and methanol to oil ratio are the independent variables considered. Fatty acid methyl ester (FAME) production yields obtained during reaction process is the chosen response. The result from analysis of variance (ANOVA) showed a satisfactory result. Moreover, the input variables showed greater significance on the response which are reaction time and temperature base on F and P-value. The statistical models used in forecasting biodiesel production yield revealed a significant accordance with the experimental as well as the predicted value ($R = 0.9686$). An optimum methyl ester yield of 93.29 % was achieved with methanol-oil optimal molar ratio of 6:1, 120 min reaction time, 60°C temperature, and 1.0 wt% catalyst concentration. The features of the produced biodiesel falls in the range recommended by ASTM standard.

Research Highlights

1. The selected model for FAME percentage rate of conversion is satisfactory
 2. The significance of the model was justified from higher values from both coefficients
 3. FAME percentage rate of conversion increases with an increasing rate of reaction time and catalyst concentration
 4. FAME yield production increases as catalyst concentration and methanol to oil ratio increase.
-

Graphical Abstract

Fig. 1. Surface plot between methanol to oil ration and reaction temperature.

Research Objectives

Several parameters such as reaction temperature, agitation speed, alcohol/oil ratio, reaction time and catalyst concentration affect the production yield of biodiesel from vegetable oils transesterification. The optimization process will required multiple experiments alongside a mathematical model to predict the change in individual process parameter as well as its interactions. A number of methodologies have were successfully used in optimizing the production of biodiesel from different kind of raw materials with different kind of catalysts. In this study, RSM was used to optimized the transesterification of crude coconut seed oil with $\text{CaO} / \text{Al}_2\text{O}_3$ as heterogeneous catalyst.

Methodology

Coconut oil was extracted from coconut seeds using Soxhlet extraction. All chemical reagents used were of analytical grades and were obtained from Department of pure and Applied Chemistry laboratory, UDUS, Sokoto state, Nigeria. Commercial CaO was used in the preparation of the solid catalyst. Aluminum oxide (20 g) were accurately weighed and dissolved in 100 cm^3 of distilled water, another (5 g) calcium oxide powder were weighed and added to the same solution, and stirred at room temperature, the mixture was then placed on a hot plate and heated for 5 min at a temperature of 50°C at 300 r.p.m for 2 hr the mixture was

then dried in an oven at 105 °C, and transferred into the crucibles and placed into the furnace and calcined at 600 °C for 2 hr [1]

The synthesis of biodiesel was optimized using (RSM) Box-behnken design (BBD) using MINITAP-17 statistical software. The independent variables reaction temperature, agitation speed, alcohol/oil ratio, reaction time and catalyst concentration. Fatty acid methyl ester (FAME) production yields obtained during reaction process is the chosen response. Table 1 lists the four independent variables levels. The overall design matrix for the BBD design with the actual independent variable and response were shown in Table 2. The optimization process was randomly run to reduce errors in the systematic trends. Studies shows that, BBD could be the best in dealing with sequential experiments due to reduced in number of design points for testing lack of fit [2]

Results

Table 1: Experimental variables and their levels

Factors	Low Level	High Level
Time (min)	120	180
Catalyst (wt%)	0.5	1.5
Methanol/Oil Ratio	3:1	9:1
Temperature (°C)	50	60

Table 1 above shows the independent experimental variables and their levels for the biodiesel reaction. Twenty-seven experiments were conducted in a randomized order. Results for actual and predicted biodiesel yield from the BBD output are shown in Table 2. The actual biodiesel yield varied between 63.64% and 93.29% at catalyst concentration of 1.0 %, 6:1 molar ratio of methanol-to-oil, reaction time of 120 min, and 50°C reaction temperature.

Table 2: BBD experimental design showing the predicted and actual yield from coconut oil transesterification

Run Order	Temp (°C)	Time (min)	Catalyst		Methanol to oil ratio	Actual Yield	Predicted Yield
			conc (wt%)				
1	55	150	1.5		9	78.26	80.13
2	55	120	1.5		6	82.03	80.82
3	60	120	1		6	93.29	93.66
4	60	150	0.5		6	88.73	89.22
5	55	180	1		9	90.42	88.91
6	55	150	1.5		3	75.31	76.34
7	55	150	1		6	91.48	91.48

8	60	150	1.5	6	90.28	90.61
9	55	120	1	9	70.27	67.93
10	55	150	1	6	92.48	91.48
11	55	150	0.5	9	73.87	75.41
12	55	120	0.5	6	80.29	79.24
13	50	180	1	6	90.66	92.86
14	55	150	1	6	90.48	91.48
15	55	120	1	3	76.04	75.87
16	55	180	1	3	72.90	73.56
17	60	180	1	6	89.28	87.48
18	55	180	1.5	6	93.10	93.22
19	60	150	1	3	84.59	84.21
20	55	150	0.5	3	71.09	71.79
21	50	150	1	9	78.33	77.78
22	60	150	1	9	78.41	79.36
23	50	150	1	3	67.41	65.53
24	50	150	1.5	6	85.90	83.73
25	50	120	1	6	63.64	68.01
26	50	150	0.5	6	77.85	75.84
27	55	180	0.5	6	85.23	85.52

Findings

In this work, the transesterification process has been optimized for crude coconut oil using $\text{CaO}/\text{Al}_2\text{O}_3$ as heterogeneous catalysts. The result obtained from analysis of variance (ANOVA) is satisfactory result. Moreover the input variables that showed greater significance on the output (biodiesel yield) are reaction time and temperature base on F and P-value. The statistical models made in predicting biodiesel production yield revealed an extend of reasonable agreement in accordance with the predicted and experimental value ($R = 0.9686$). An optimum methyl ester yield of 93.29 % was achieved with optimal conditions of 6:1 molar ratio of methanol-oil, temperature of 60°C , 120 min time of reaction and 1.0 wt% catalyst concentration. The features of the produced biodiesel falls in the range recommended by ASTM standard.

REFERENCES

- [1] N.P. Asri, S. Soe'eib, B. Poedjojono, Suprpto, Alumina supported zinc oxide catalyst for production of biodiesel from kesambi oil and optimization to achieve highest yields

- of biodiesel, Euro-Mediterranean J. Environ. Integr. (2018). doi:10.1007/s41207-017-0043-8.
- [2] W.A. Jensen, Response Surface Methodology: Process and Product Optimization Using Designed Experiments 4th edition, J. Qual. Technol. (2017). doi:10.1080/00224065.2017.11917988.

Author's Biography

Jamilu Usman, Lecturing and Research at Department of Chemistry, Sokoto State University, Nigeria