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Research Article

Optimization of Oil Extraction from *Carica papaya* (Pawpaw) Seed for Biodiesel Production

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Abstract

The global search for renewable and sustainable energy sources has triggered research on biodiesel production using non-edible oils. This study investigates the optimization of oil extraction from *Carica papaya* (pawpaw) seeds and subsequent biodiesel production using acid-treated catalysts derived from corn pod agricultural waste. Three catalysts were synthesized: Acidified Submerged Fermented Burnt Corn Pod Powder (ASFBCPP), Acidified Non-Fermented Burnt Corn Pod Powder (ANFBCCP), and Sodium hydroxide (NaOH). These catalysts were thoroughly characterized using Scanning Electron Microscopy (SEM-EDS), Fourier Transform Infrared Spectroscopy (FTIR), X-ray Fluorescence Spectroscopy (XRF), Thermogravimetric Analysis (TGA), Brunauer-Emmett-Teller (BET), and Zeta Potential analysis. Transesterification was optimized using Response Surface Methodology (RSM) with Box-Behnken Design (BBD) and Artificial Neural Network-Genetic Algorithm (ANN-GA). Results revealed that ASFBCPP and ANFBCCP catalyzed biodiesel yields of over 99% under optimized conditions, outperforming the traditional NaOH catalyst. The produced biodiesel met the ASTM D6751 and EN 14214 standards. The study underscores the potential of *Carica papaya* seed oil and corn pod-based catalysts for sustainable biodiesel production.

Keywords: Acidified Corn Pod; Biodiesel, Biocatalyst; *Carica papaya*; Oil Extraction; RSM-BBD; ANN-GA; and Renewable Energy

Introduction

Human survival depends on a consistent energy supply for economic development, and as technology and populations grow, energy demand rises while supply remains limited. It is obvious that without a continuous energy supply, no country or state can sustain its economic development [1,2]. Conventional sources, primarily fossil fuels, contribute significantly to environmental degradation [3-5]. As energy demand increases, the environmental regulations tighten, and attention has shifted to renewable energy sources [6]. This has highlighted the reasons behind the global search for alternative energy sources, and it has escalated the demand for renewable energy, which has spotlighted biodiesel as a viable alternative to fossil fuels [3,7]. Traditional biodiesel production relies on edible oils, which raises ethical and economic concerns related to food security [8-10]. The development of efficient, eco-friendly catalysts and biodiesel is essential for enhancing biodiesel production processes, supporting a circular economy [11], and minimizing greenhouse gas emissions from waste decomposition [12-14]. Therefore, attention has turned to non-edible sources of agricultural residues [15].

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Carica papaya seeds, often discarded as waste, offer a non-competitive and sustainable oil source for biodiesel production [1]. *Carica papaya* seeds are rich in oil, and widely available in tropical regions; these seeds align with the Sustainable Development Goals [16]. Moreover, catalyst development has a pivotal role in biodiesel synthesis. The use of corn pod waste as a catalyst not only reduces production costs but also promotes waste valorization [5,12].

This study delves into the combined use of *Carica papaya* seed oil and acidified corn pod-based catalysts for biodiesel synthesis. Advanced modeling techniques like Response Surface Methodology (RSM) with Box-Behnken Design (BBD) and Artificial Neural Networks (ANN) enhanced with Genetic Algorithms (GA) were employed to optimize process parameters, ensuring high yield and efficiency. Also, various characterization techniques, including FTIR, SEM, XRD, XRF, TGA, and BET surface area analysis, were employed to analyze the catalyst. The biodiesel's quality was assessed against established standards to evaluate its potential as an alternative biodiesel.

Materials and Methods

Materials procurement and preparation

Carica papaya seeds were obtained from a farm at Ughelli, Delta State, Nigeria (latitude: 6.131293° E, longitude: 5.324928° N). *Carica papaya* seeds were cleaned and dried to a constant weight. Corn pods were sourced, cleaned, and processed to develop the biocatalyst.

Extraction of *Carica papaya* Oil

The dried papaya seeds were oven-dried at 240°C for two hours, ground to a particle size of 0.25 µm, and then subjected to solvent extraction with n-hexane using a Soxhlet apparatus across seventeen experimental runs. Extraction parameters, including sample weight, extraction time, and solvent volume, were optimized using RSM to maximize oil yield. The extracted oil was analyzed for physicochemical properties such as density, acid value, free fatty acid value, and saponification value [17]. The oil yield percentage was calculated using Equation (1).

$$OY\ (\%) = \frac{Wt_{oil}}{Wt_{powder}}\ X\ 100 \text{ --------(1)}$$

Where Wt_{oil} is the weight of the extracted oil, is the weight of powder used, and is the oil yield.

Preparation of acidified corn pod biocatalyst

Corn pods were fermented, dried, and burnt in the open air at high temperatures. The resulting material was treated with 0.1 M of hydrochloric acid to enhance its catalytic properties. Procedural methods outlined by Akhabue [18], were adopted to characterize the catalysts.

Catalyst characterization

- SEM-EDS: Determined surface morphology and elemental composition.
- FTIR: Identified functional groups.
- XRF: Measured elemental composition.
- TGA: Analyzed thermal stability.
- BET: Determined surface area and porosity.
- ZETA: Assessed surface charge and stability.

Biodiesel production process

The fatty acid methyl ester (FAME) production from papaya seed oil was conducted using the prepared acidified corn pods biocatalyst, as explained by Eboibi [2]. Process variables, such as *Carica papaya* Seed weight powder, volume of solvent, and contact time, were optimized using a Box-Behnken design (BBD) and an artificial neural network coupled with a genetic algorithm (ANN-GA) to achieve the maximum biodiesel yield.

Optimization techniques

- RSM-BBD: Employed for modeling and analyzing interactions between variables. RSM- BBD provides sufficient degrees of freedom to develop cubic models, which is beneficial when experimental errors may occur [19,20].
- ANN-GA: Used for training and prediction using a multilayer perceptron and genetic algorithm.

Results and Discussion

Characterization of catalyst

SEM-EDS analysis for the derived catalyst

The results of the SEM-EDS analysis are presented in Figure 1a and 1b. SEM-EDS analysis revealed its morphology at magnifications of 8000X and 9000X. The image in Figure 1[a-b] depicts rough, porous surfaces suitable for adsorption. This is a result of the thermal treatment during catalyst preparation, leading to a high carbon content from the complete breakdown of calcium trioxocarbonate. This enhances the absorption of alcohol during the transesterification reaction.

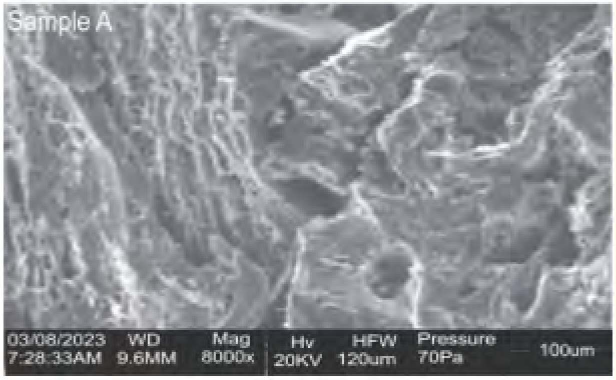


Figure 1(a): SEM-EDS Spectrum Results

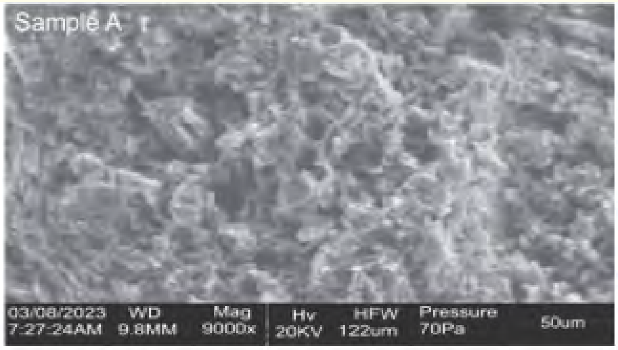


Figure 1(b): SEM-EDS Spectrum

FTIR evaluation of the derived catalyst

FTIR confirmed the presence of active sites like K_2O and CaO, suggesting the thermal breakdown of calcium carbonate and potassium produced K_2O, CaO, and CO_3^2, suggesting the catalyst originated from agricultural biomass waste and during the 0.1 M HCl acid impregnation, unwanted compounds were absorbed, resulting in a high alkali concentration in the derived catalyst utilized to convert triglycerides. The rough catalyst surface as presented in Figure 1 depicts alcohol impregnation during the synthesis of biodiesel due to its porous nature and large porous aperture makes room for the catalyst surface to undergo acid leaching, which aids high FFA oil [15]. Furthermore, the XRF showed quartz (SiO_2), orthoclase, and illite, which are essential in biodiesel conversion.

Thermogravimetric analysis (TGA) evaluation of the derived catalyst

The results of the thermogravimetric analysis are presented in Figure 2. Thermogravimetric analysis (TGA) was used to assess temperature-dependent mass changes in the derived catalyst, and TGA confirmed high thermal stability. Figure 2 illustrated the TGA analysis and that weight loss of the catalyst increased with temperature between 26.48 and 31.01 °C, and a slight mass decrease of about 0.001% was observed from 32.77 to 38.82 °C, the weight remained constant at 100.141%, at 846.87 °C, a significant weight reduction was recorded, with only 4.952% of the sample remaining.

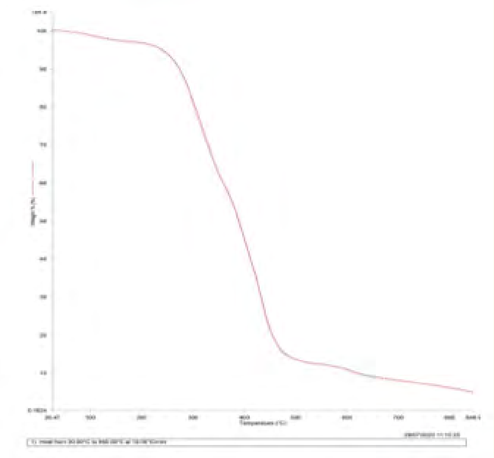


Figure 2: TGA plot for the Derived Catalyst.

BET evaluation of the derived catalyst

BET analysis indicated a high surface area. This analysis revealed various catalysts' total basic densities, pore volumes, and surface areas. The results indicated that physical absorption occurred when an inert gas was adsorbed onto the solid surface. The findings showed a negative correlation between pore diameter and the volume accessible for adsorbate monolayer development.

Evaluation of ZETA potential

ZETA analysis demonstrated stable interaction with oil and methanol. The catalyst's potential efficacy as an energy carrier is essential due to its stability throughout the transesterification process of biodiesel as presented in Figure 3 in the appendix. A positive zeta potential indicates that suspended particles contribute to stability by having a positive charge, whereas a negative zeta potential suggests particle agglomeration [21].

Biodiesel synthesis and optimization process

A biodiesel production process utilized a single-batch reactor with three necks. A specified volume of oil was heated to 100°C for 30 minutes. A magnetic stirrer was used on a hot plate to dissolve the catalyst in ethanol. The solution was introduced into the preheated oil in the reactor, with the hot plate set to an output of 120W to facilitate the reaction. Afterward, the mixture was separated using a high-speed centrifuge (model MSLZL19) at 10,000 rpm for 10 minutes. The biodiesel was then dried with calcium chloride and rinsed with deionized water. The weight of the final dried biodiesel was calculated using Equation (2).

$$PBY = \left(\frac{\forall Q_{BP}}{\forall Q_{Oil\ used}}\right) X\ 100 \text{ ----------(2)}$$

Where is a percentage of biodiesel, weight of biodiesel, Weight of oil.

Optimization of biodiesel

A total of 17 experimental runs were carried out for biodiesel synthesis using each catalyst treatment. The data were analyzed using response surface methodology with a Box-Behnken design (RSM-BBD), alongside artificial neural networks optimized through genetic algorithms (ANN-GA), as illustrated in Table 1.

Variables	**Units**	**Symbols**	**Levels**		
			-1	**0**	**+1**
Amount of cation	(w)	Q_1	2.0	3.0	4.0
contact time	(min)	Q_2	60	70	80
EOH/OMR	(v/v)	Q_3	4	5	6

Table 1: RSM- BBD-Based Experimental Design for Biodiesel Production.

Where w= weight, v/v= volume per volume.

Employing of ASFBCPP catalyst

ASFBCPP yielded 99.06% of biodiesel using RSM-BBD and 98.78% using ANN-GA, as presented in Table 2 in the appendix. Also, the ANOVA results (Table 3) in the appendix identified significant variables with p-values < 0.05. The model showed a strong fit, with an R^2 of 99.85% and adjusted R^2 of 99.41%, and an adequate precision of 49.27. The regression equation (Eq. 3) helped assess factor impacts on yield.

$$\begin{aligned} \text{OY }\%(\text{w/wt}) &= 96.64 + 0.89\mu_1 + 0.335\mu_2 + 0.535\mu_3 - 0{,}05\mu_1\mu_2 + 0.545\mu_1\mu_3 \\ &-0.265\mu_2\mu_3 - 3.34\mu_1{}^2 + 1.35\mu_2{}^2 + 0.345\mu_2{}^2 + 0.000\mu_1\mu_2\mu_3 + 1.36\mu_1{}^2\mu_2 + 3.26\mu_1{}^2\mu_3 \\ &-0.495\mu_1\mu_2{}^2 + 0.000\mu_1\mu_3{}^2 + 0.000\mu_2\mu_3{}^2 + 0.000\mu_1{}^3 + 0.000\mu_2{}^3 + 0.000\mu_3{}^3 \text{ (3).} \end{aligned}$$

Std. Run	**Amount of Cation (g)**	**Contact time (min)**	**EOH/OMR (v/v)**	**Biodiesel yield (% w/w)**	**ARSM-BBD (% w/w)**	**AANN-GA (% w/w)**
1	2	60	5	90.20	90.20	90.20
2	4	60	5	96.70	96.70	96.34
3	2	80	5	98.88	98.88	98.88
4	4	80	5	96.00	96.00	96.00
5	2	70	4	98.94	98.94	98.94
6	4	70	4	96.00	96.00	96.34
7	2	70	6	96.40	96.64	96.40
8	4	70	6	92.50	92.50	92.50
9	3	60	4	96.80	96.64	96.34
10	3	80	4	96.80	96.64	96.34

11	3	60	6	96.40	96.64	96.34
12	3	80	6	93.40	93.40	93.40
13	3	70	5	97.20	97.20	96.34
14	3	70	5	89.50	89.50	96.34
15	3	70	5	96.80	96.64	96.34
16	3	70	5	98.80	98.80	96.34
17	3	70	5	98.40	98.40	96.34

Table 2: Variable factors, experimental results, and anticipated values for the ASFBCPP Catalyst.

Source	Sum of Squares	Df	Mean Square	F-value	p-value	Inference
Model	129.11	12	10.76	224.15	< 0.0001	Significant
	3.20	1	3.20	66.75	0.0012	Significant
	0.4489	1	0.4489	9.35	0.0377	Significant
	1.14	1	1.14	23.85	0.0081	Significant
	0.0100	1	0.0100	0.2083	0.6718	Non- significant
	1.19	1	1.19	24.75	0.0076	Significant
	0.2809	1	0.2809	5.85	0.0728	Non-significant
^{2}	46.97	1	46.97	978.56	< 0.0001	Significant
^{2}	7.67	1	7.67	159.87	0.0002	Significant
^{2}	0.5012	1	0.5012	10.44	0.0319	Significant
	0.0000	0	-	-	-	
^{2}	3.73	1	3.73	77.63	0.0009	Significant
^{2}	21.26	1	21.26	442.82	< 0.0001	Significant
^{2}	0.4900	1	0.4900	10.21	0.0331	Significant
^{2}	0.0000	0	-	-	-	-
^{2}	0.0000	0	-	-	-	-
^{2}	0.0000	0	-	-	-	-
^{3}	0.0000	0	-	-	-	-
^{3}	0.0000	0	-	-	-	-
^{3}	0.0000	0	-	-	-	-
Pure Error	0.1920	4	0.0480	-	-	-
Cor Total	129.30	16	-	-	-	-

Table 3: Cubic model ANOVA for variable response Catalyst ASFBCPP.

Also, Figure 3 [a–c] presents three-dimensional graphs depicting the interactions between variable pairs and their effects on biodiesel yield. The most influential interaction was between the catalyst amount and ethanol-to-oil ratio. Optimal conditions (3.961 g catalyst, 72.423 min, 1:5.990 ratio) yielded 99.15% biodiesel, with 99.06% confirmed experimentally. A triple mean validated the result. The ANN-GA results also illustrate the relationship between biodiesel yield and the interactions among the independent variables are illustrated through 3D surface plots (Figure 4[a–c]), which visually demonstrate how variations in the input factors collectively influence the overall yield.

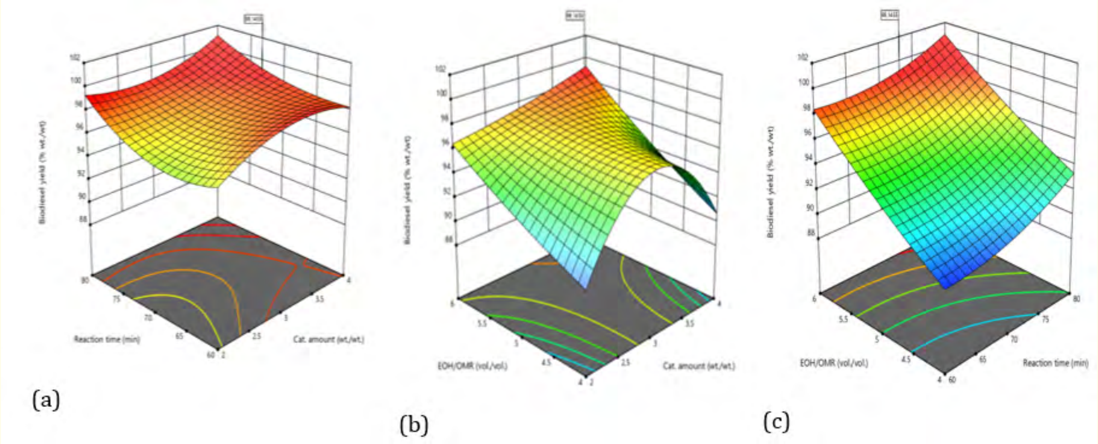


Figure 3 (a-c): 3-dimensional graphs by RSM-BBD.

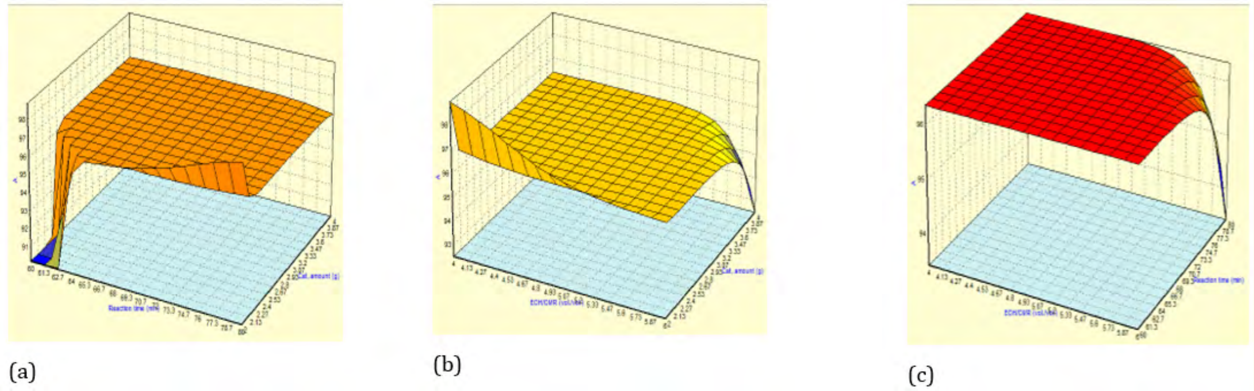


Figure 4 (a-c): ANN-GA Three-Dimensional Contour Graphs.

A case of employing ANFBCCP as a catalyst

ANFBCCP achieved 99.02% and 99.28%, respectively, as presented in Table 4 in the Appendix. The analysis in Table 4 highlights how the biodiesel yield is affected by the reagent amount, reaction temperature, and the ethanol-to-oil molar ratio (EOH/OMR). Table 5 in the appendix provides ANOVA results, showing all model factors are significant ($p < 0.05$), except for the quadratic term ($p = 0.0823$). High R^2 values confirm a strong model fit. Equation (4) allows for yield prediction and comparison of factor impacts.

$$\mathrm{BY\%}(w/w) = 51.41 + 0.85D_1 + 52.00D_2 - 26.13D_3 - 0.51D_1D_2 + 0.06D_1D_3 - 0.67D_2D_3 + 0.003D_1^2 - 2.06D_2^2 + 2.34D_3^2 \quad (4)$$

Std. Run	Amount of Cation (g)	Contact time (min)	EOH/OMR (v/v)	Biodiesel yield (% wt./wt.)	APRSM-BBD (% wt./wt.)	APANN-GA (% wt./wt.)
1	70	3	5	94.94	94.94	96.655
2	70	3	5	94.94	98.23	96.655
3	70	3	5	94.94	94.94	96.655
4	70	3	5	94.94	95.01	96.655
5	70	3	5	94.94	94.94	96.655
6	70	4	6	94.61	96.77	99.112

7	70	2	6	94.98	97.94	98.639
8	70	4	4	96.80	87.22	98.396
9	70	2	4	94.49	94.82	97.171
10	80	3	6	98.48	97.49	98.896
11	60	3	6	96.26	88.89	95.979
12	80	3	4	97.58	98.57	89.958
13	60	3	4	97.90	94.94	89.721
14	80	4	5	88.77	98.15	96.758
15	60	4	5	98.88	96.35	95.927
16	80	2	5	97.64	94.94	93.423
17	60	2	5	87.34	94.28	92.529

Table 4: Variables Factors, Experimental Results, and the Anticipated Values using ANFBCPP.

Source	Sum of Squares	df	Mean Square	F-value	p-value	Level of significance
Model	150.71	9	16.75	214.16	< 0.0001	Significant
D_1	0.5460	1	0.5460	6.98	0.0333	
D_2	2.66	1	2.66	33.98	0.0006	
D_3	0.7442	1	0.7442	9.52	0.0177	
D_1D_2	104.14	1	104.14	1331.92	< 0.0001	
D_1D_3	1.61	1	1.61	20.63	0.0027	
D_2D_3	1.80	1	1.80	22.96	0.0020	
D_1^2	0.3213	1	0.3213	4.11	0.0823	
D_2^2	17.85	1	17.85	228.24	< 0.0001	
D_3^2	23.03	1	23.03	294.55	< 0.0001	
Residual	0.5473	7	0.0782	-	-	
Lack of Fit	0.5473	3	0.1824	-	-	not significant
Pure Error	0.0000	4	0.0000	-	-	
Cor. Total	884.02	16	-	-	-	
	RSM_{BBD}					
R^2	99.64%					
Adj. R^2	99.17%					
Pred. R^2	94.21%					
Std. Dev.	0.2796					

Table 5: Analysis of Variance for Regression Analysis using ANFBCPP Catalyst.

The effects of the interactions , , and D_2D_3 on biodiesel yield were analyzed using 3D contour plots (Figures 5 [a–c]). While all interactions were significant, the (catalyst amount and reaction time) had the greatest impact. Evaluating the optimal yield was predicted at 99.09% (w/w), achieved with 2.19 g catalyst, 79.78 min reaction time, and a 1:5.60 EOH/OMR ratio. This was validated with a confirmed average yield of 99.02% (w/w).

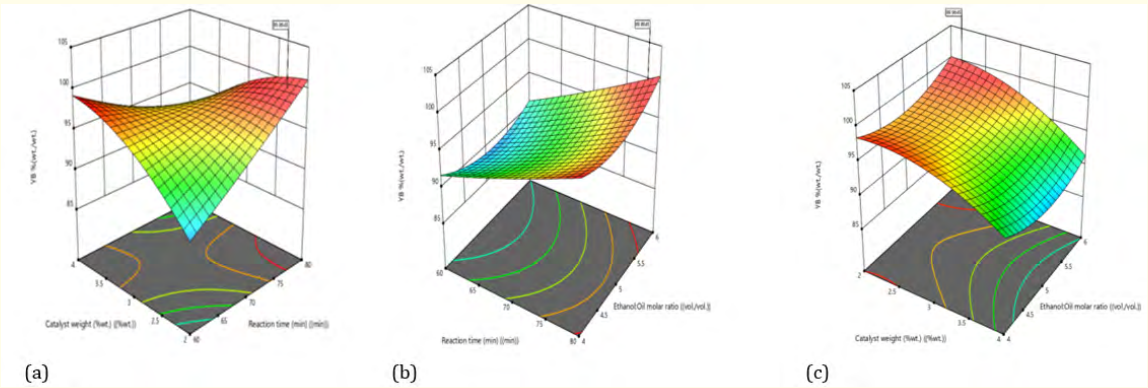


Figure 5 (a-c): 3-dimensional graphs by RSM-BBD.

Also, the ANN-GA results indicate high R^2 and predicted R^2 values, confirming strong accuracy. The RMSE of 0.1516 confirmed precise predictions, while a standard deviation of 15.76 showed low output variation. The findings are depicted in three-dimensional visualizations of the response, as depicted in Figures 6 (a-c).

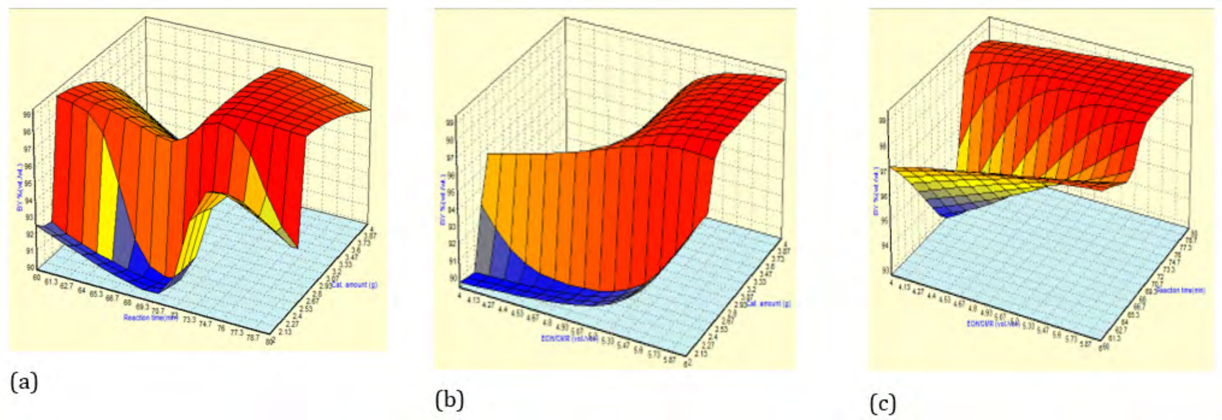


Figure 6 (a-c): ANN-GA three-dimensional contour graphs.

A case of employing NaOH as a catalyst

NaOH performed comparatively lower with 85.87% (RSM-BBD) and 88.12% (ANN-GA).

Table 6 in the appendix shows the optimized biodiesel yields (ARSM-BBD) achieved through process improvements. ANOVA results in Table 7 in the appendix confirm the model's validity, with most factors statistically significant ($p < 0.05$), except for the interaction ($p = 0.3904$) and quadratic term ($p = 0.3134$). High R^2, adjusted R^2, and predicted R^2 values indicate an excellent model fit. Equation (5) can be used to estimate biodiesel yields and analyze the influence of individual variables.

$$\mathrm{BY\%}(w/w) = 86.16 + 2.72T_1 + 3.17T_2 + 1.13T_3 - 0.195T_1T_2 + 0.775T_1T_3 - 1.72T_2T_3 - 2.06T_1^2 + 1.10T_2^2 + 0.2255T_3^2 \quad (5)$$

Also, 3D plots in (Figure 8[a–c]) illustrated the interactions between variable pairs (, ,), and their effects on biodiesel yield. All interactions were significant, with the cation amount and contact time showing the strongest influence. The process was evaluated across 100 trials to determine the optimal yield. The predicted maximum yield was 87.14% (w/w), achieved with 2.08 grams of catalyst, 79.70 minutes of reaction time, and an ethanol-to-organic matter ratio of 1:4.07, respectively.

Std. Run	Amount of Cat (g)	Contact time (min)	EOH/OMR (vol./vol.)	Biodiesel yield (% (w/w)	ARSM-BBD (% w/w)	AANN-GA (%) w/w)
1	70	3	5	81.09	81.25	83.70
2	70	3	5	85.42	86.16	83.70
3	70	3	5	84.79	85.13	83.70
4	70	3	5	85.00	84.94	83.70
5	70	3	5	82.20	81.92	83.70
6	70	4	6	91.00	90.78	91.00
7	70	2	6	86.42	86.16	86.42
8	70	4	4	86.34	86.16	86.34
9	70	2	4	82.31	81.97	82.31
10	80	3	6	79.00	79.12	79.00
11	60	3	6	89.11	88.95	89.11
12	80	3	4	90.24	90.52	90.24
13	60	3	4	86.32	86.16	86.32
14	80	4	5	85.78	85.84	85.78
15	60	4	5	86.32	86.16	86.32
16	80	2	5	91.00	90.88	90.99
17	60	2	5	86.50	86.72	86.50

Table 6: Experimental results, variable factors, and the anticipated values for NaOH Catalyst.

Source	Sum of Squares	Df	Mean Square	F-value	p-value	Level of significance
Model	180.55	9	20.06	110.51	< 0.0001	Significant
T1	58.97	1	58.97	324.85	< 0.0001	
T2	80.14	1	80.14	441.45	< 0.0001	
T3	10.31	1	10.31	56.77	0.0001	
T1T2	0.1521	1	0.1521	0.8379	0.3904	
T1T3	2.40	1	2.40	13.23	0.0083	
T2T3	6.40	1	6.40	35.26	0.0006	
$\mathrm{T1}^{2}$	17.95	1	17.95	98.86	< 0.0001	
$\mathrm{T2}^{2}$	5.05	1	5.05	27.84	0.0012	
$\mathrm{T3}^{2}$	0.2141	1	0.2141	1.18	0.3134	
Residual	1.27	7	0.1815			
Lack of Fit	0.5720	3	0.1907	1.09	0.4489	not significant
Pure Error	0.6987	4	0.1747			
Cor. Total	181.82	16				
$\mathrm{RSM}_{\mathrm{BBD}}$						
R^2	99.30%					
Adj. R^2	98.40%					
Pred. R^2	94.37%					
Std. Dev.	0.4261					

Table 7: ANOVA Regression Analysis for NaOH Catalyst.

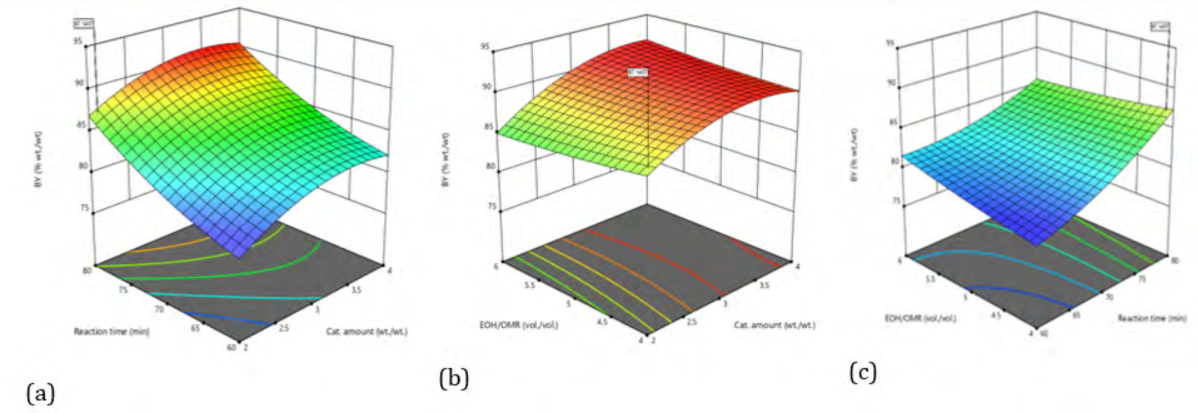


Figure 7 (a-c): RSM-BBD 3-dimensional graphs.

Also, using ANN-GA, in achieving optimal results as illustrated in Figure 8 (a-c), depicts high R^2, and predicted R^2 values confirm model reliability. Despite an RMSE of 0.9650 above the ideal 0.2–0.5 range, the model still indicates strong predictive power, with low standard deviation and variance suggesting consistent performance.

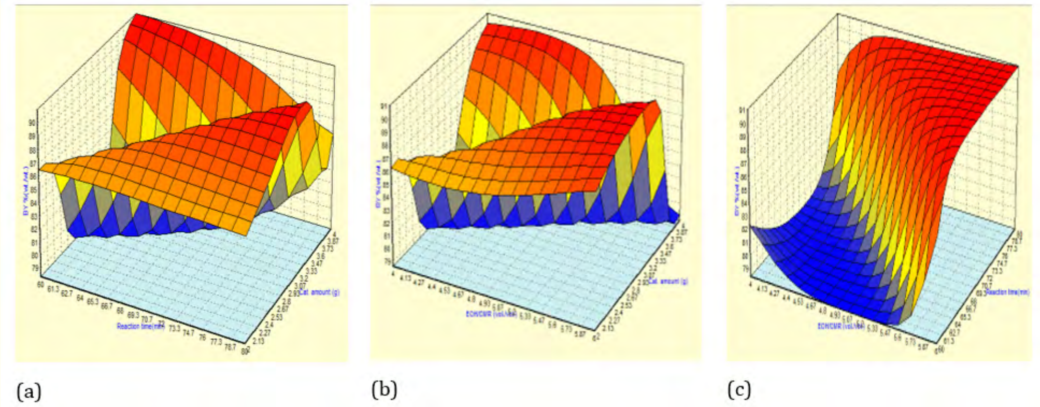


Figure 8: ANN-GA 3D contour plots.

RSM-BBD provided a better model fit for ASFBCPP ($R^2 = 0.9985$), while ANN-GA was superior for ANFBCCP and NaOH. ANN-GA showed high predictive capability and robustness.

Biodiesel fuel quality/characteristics

The produced biodiesel conforms to the specifications set by ASTM D6751 and EN 14214 standards [22,23], with desirable viscosity, cetane number, density, acid value, and moisture content as presented in Table 8.

Catalyst reusability test

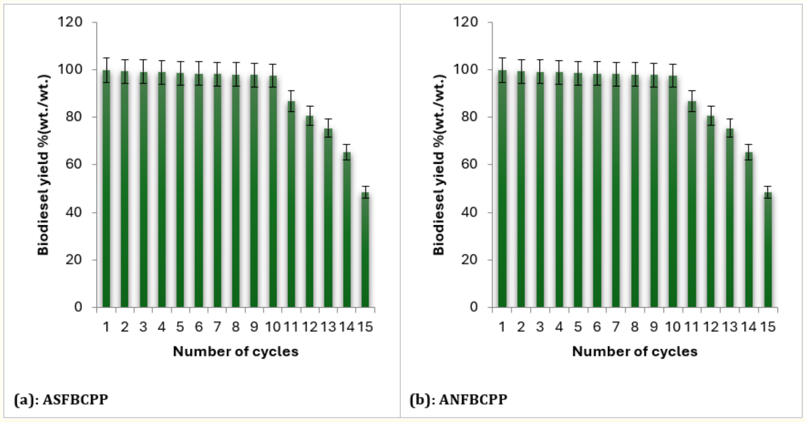
Catalysts maintained efficiency up to 10 reuse cycles. Decline was observed beyond the 11th cycle, as illustrated in Figure 9, indicating reduced catalytic activity due to pore collapse and elemental leaching.

Conclusion

Based on the results of this research, the following conclusion can be drawn:

Parameters	**$B_{ASFBCPP}$ %(w/w)**	**$B_{ANFBCPP}$ %(w/w)**	**BNaOH %(w/w)**	**ASTM D6751**	**EN 14214**
Colour@ room temp.	Dark-Brown	Dark -Brown	Brownish-yellow	-	-
Density (kg/m^3) @ 40 ^{0}C	890	892	894	-	860-900
Viscosity @ 40 ^{0}C/ (mm^2/s)	3.67	4.20	5.50	1.9-6.0	3.5-5.0
Moisture content (%)	<0.001	<0.001	<0.001	<0.03	0.02
%FFA (as oleic acid)	0.23	0.26	0.40	0.40 max	0.25 max
Acid value (mg KOH/g oil)	0.46	0.52	0.80	0.80 max	0.5 max
Iodine value (g I_2/100g oil)	82.45	84.30	76.65	-	120 max
Saponification value (mg KOH/g oil)	120.40	122.30	140.35	-	-
Peroxide value (meq O_2/kg oil)	8.54	9.10	11.64	-	12.85
HHV (MJ/kg)	43.26	43.15	42.53	-	-
Cetane number	73.08	65.33	67.94	57 min	51 min
API	26.60	27.13	26.78	39.95 max	-
Diesel index	87.61	76.85	80.47	50.4 min	-

Table 8: Characteristics of Biodiesel Produced.



(a): ASFBCPP

(b): ANFBCPP

Figure 9: Catalyst reusability test plot for ASFBCCP and ANFBCPP.

- *Carica papaya* seed is a promising non-edible oil source.
- Acidified corn cob catalysts (ASFBCPP and ANFBCCP) are effective and sustainable.
- Biodiesel yields above 99% were achieved under optimized conditions.
- RSM-BBD and ANN-GA effectively modeled and optimized the process.
- The biodiesel produced conforms to international fuel standards.
- Catalyst reusability enhances process sustainability and economic viability.

Bibliography

1. Nyorere O., *et al*. “Dataset on bio-catalysis of agro-waste in acidic medium for conversion of pink solo Carica papaya seed oil to biodiesel fuel”. *Data in Brief* (2024a).
2. Eboibi O., *et al*. “Comparative analysis of the fuel properties of biodiesel produced from different groundnut varieties”. *International Journal of Advanced Academic Research* 8.9 (2022): 10-23
3. Ajala EO., *et al*. “Calcium-carbide residue: A precursor for the synthesis of CaO–Al2O3–SiO2–CaSO4 solid acid catalyst for biodiesel production using waste lard”. *Chemical Engineering Journal Advances* 4 (2020): 100033.
4. Bargole SS., *et al*. “Valorization of low fatty acid content waste cooking oil into biodiesel through transesterification using a basic heterogeneous calcium-based catalyst”. *Biomass and Bioenergy* 146 (2021): 105984.
5. Adepoju TF. “Synthesis of biodiesel from Pig fat oil - Neem oil blend using the mixture of two agricultural wastes: palm kernel shell husk (PKSH) and fermented kola nut husk (FKNH*)”. Industrial Crops and Products* 149 (2020): 112334.
6. Adepoju T F., *et al*. “An application of non-edible oils, bio-based catalysts, and process optimization as an economical route for a hybridized oil biodiesel synthesis”. *Case Studies in Chemical and Environmental Engineering* 6 (2022): 100231.
7. Khan HM., *et al*. “Application of agricultural waste as a heterogeneous catalyst for biodiesel production”. *Catalysts* 11 (2021): 1215.
8. Dhawane SH., *et al*. “Biodiesel synthesis from Hevea brasiliensis soil employing carbon supported heterogeneous catalyst: Optimization by Tanquchi method”. *Renewable Energy* 89 (2016): 506–514.
9. Anietie OE., *et al*. “Evaluation of in-situ and ex-situ hybridization in the optimized transesterification of waste and pure vegetable oils”. *Biofuels, Bioproducts and Biorefining* (2022).
10. Sinebe E J and Uguru H. “The Effects of Plants Essential Oils on Biodiesel Fuel Properties during Storage”. *IPS Journal of Engineering and Technology* 1.2 (2025): 70–74.
11. Nyorere O and Oluka SI. “Impact of Optimization on Carica papaya Seeds Oil Extraction”. *Explorematics Journal of Innovative Engineering and Technology* 5 (2024): 34-41.
12. Mohlala LM., *et al*. “Beneficiation of corn cob and sugar cane bagasse for energy generation and materials development in Nigeria and South Africa. A Short Review”. *Alexander Engineering Journal* 52.3 (2016): 3025-3036.
13. Kumar J., *et al*. “The optimization of biodiesel production from waste cooking oil catalyzed by ostrich-eggshell derived CaO through various machine learning approaches”. *Cleaner Energy Systems* 3 (2022): 100033.
14. Noor A and Khan SA. “Agricultural waste as renewable biomass to remediate water pollution”. *Sustainability* 15.5 (2023): 4246.
15. Nyorere O., *et al*. “Production of biodiesel from biocatalysis of agro-wastes in acidic environment”. *Scientific African* 24 (2024b): e02154.
16. Sharma A., *et al*. “Phytochemistry, pharmacological activities, nano-particle fabrication, commercial products and waste utilization of Carica papaya L: Comprehensive review”. *Current Research and Biotechnology* 2 (2020).
17. Abushal S A., *et al*. “Effect of storage conditions on the dietary and pharmaceutical values of ginger oil, and modeling its dielectric properties”. *Grasas y Aceites* 75.4 (2024): 2207.
18. Akhabue ER., *et al*. “Osamilite (K-Na-Ca-Mg-Fe-Al-S): A derived base catalyst for the synthesis of biodiesel from blends of pumpkin seed oil-goat fat-poultry waste fat”. *Case Studies in Chemical and Environmental Engineering* 7 (2023): 100347.
19. Almeida D., *et al*. “Response surface methodology for optimizing the production of biosurfactant by Candida tropicalis on industrial waste substrates”. *Frontiers in Microbiology* (2017).
20. Czyrski A and Jarzębski H. “Response surface methodology as a useful tool for evaluation of the recovery of the fluoroquinolones from plasma—the study on the applicability of box-Behnken design, central composite design and do Ehlert design”. *Processes* 8.4 (2020): 473 DC, USA.
21. Mahbubul MI., *et al*. “An effective ultrasonication process for better colloidal dispersion of nanofluid”. *Ultrasonics Sonochemistry* 26.4 (2015).
22. ASTM D6751. Standard Test Method for Gross Calorific Value of Oil, Water, Coal, and Coke by the adiabatic Bomb Calorimeter from SAI Global.
23. European Committee for Standardization, (EN 14214) Describing the requirements and test methods for FAME .

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