

Table 1: Results of physicochemical properties of the oil blend

Blends		Physicochemical Properties					
Ratio (BTO: WUVO)	MC (%)	SG	V @ 40 °C (mm ² /s)	AV (mgKOH/g oil)	SV (mg KOH/g oil)	IV (meq O ₂ /kg oil)	API g
BTO ₁₀	0.020	0.914	25.80	0.332	192	60.18	23.31
BTO ₂₀	0.020	0.912	24.90	0.303	189	60.03	23.65
BTO ₃₀	0.020	0.910	24.60	0.296	185	59.86	23.99
BTO ₄₀	0.020	0.905	23.50	0.283	186	59.80	24.85
BTO ₅₀	0.020	0.904	23.10	0.262	185	59.56	25.03
BTO₆₀	0.020	0.890	22.30	0.249	180	58.88	27.49
BTO ₇₀	0.020	0.902	22.52	0.252	186	58.60	25.37
BTO ₈₀	0.020	0.911	22.86	0.272	188	59.94	23.82
BTO ₉₀	0.020	0.913	22.94	0.276	191	59.70	23.48

M = Moisture content, SG = Specific gravity, V = Viscosity, AV = Acid value, IV = Iodine value, PV = Peroxide value, SV = Saponification value, API g = API gravity

Table 2: Five level- four variable- factors experimental for FAEE

Variables	Units	Symbol	Levels				
			-2	-1	0	1	2
Reaction time	(min)	X_1	60	65	70	75	80
Catalyst amount	(wt.%)	X_2	1.5	2.0	2.5	3.0	3.5
Reaction temp.	(°C)	X_3	60	65	70	75	80
EtOH/OMR	(ml/ml)	X_4	4	5	6	7	8

Table 3a: Experimental results and the predicted value

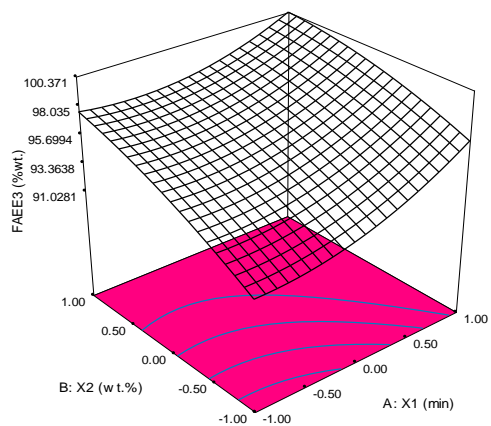
SN	X_1	X_2	X_3	X_4	FAEE3	PFAEE3
1	0.000	0.000	0.000	1.732	92.30	92.30
2	0.000	0.000	0.000	-0.269	93.80	93.80

3	-1.000	-1.000	-1.000	0.604	90.50	90.46
4	1.000	-1.000	-1.000	0.604	93.00	93.04
5	-1.000	1.000	-1.000	0.604	91.60	91.64
6	1.000	1.000	-1.000	0.604	91.70	91.66
7	-1.000	-1.000	1.000	0.604	90.90	90.94
8	1.000	-1.000	1.000	0.604	96.24	96.20
9	-1.000	1.000	1.000	0.604	97.20	97.16
10	1.000	1.000	1.000	0.604	99.80	99.84
11	1.518	0.000	0.000	-1.050	99.40	99.40
12	-1.518	0.000	0.000	-1.050	93.00	93.00
13	0.000	1.518	0.000	-1.050	96.00	96.00
14	0.000	-1.518	0.000	-1.050	86.80	86.80
15	0.000	0.000	1.518	-1.050	97.90	97.90
16	0.000	0.000	-1.518	-1.050	85.00	85.00

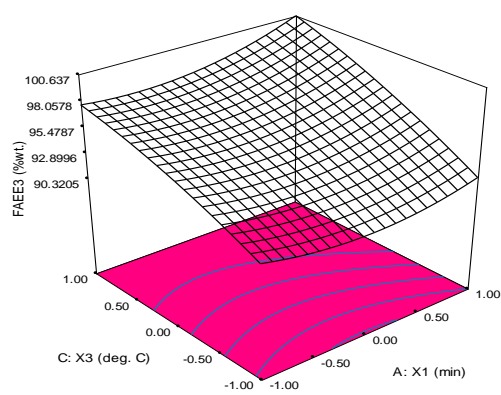
Table 3b: Anova and test of significant table

Source	Sum of Squares	df	Mean Square	F -Value	Prob > F
Model	263.03	14	18.79	1300.18	0.0217
X ₁	32.54	1	32.54	2251.71	0.0134
X ₂	44.26	1	44.26	3063.24	0.0115
X ₃	108.11	1	108.11	7481.75	0.0074
X ₄	0.56	1	0.56	38.91	0.1012
X ₁ ²	12.09	1	12.09	836.54	0.0220
X ₂ ²	2.80	1	2.80	193.46	0.0457
X ₃ ²	2.62	1	2.62	181.25	0.0472
X ₄ ²	2.20	1	2.20	152.05	0.0515
X ₁ X ₂	3.30	1	3.30	228.54	0.0420
X ₁ X ₃	3.56	1	3.56	246.67	0.0405
X ₁ X ₄	1.83	1	1.83	126.57	0.0564
X ₂ X ₃	12.65	1	12.65	875.46	0.0215
X ₂ X ₄	9.72	1	9.72	672.64	0.0245
X ₃ X ₄	12.68	1	12.68	877.26	0.0215
Residual	0.014	1	0.014	-	-
Cor Total	263.04	15	-	-	-
Fit Statistics					

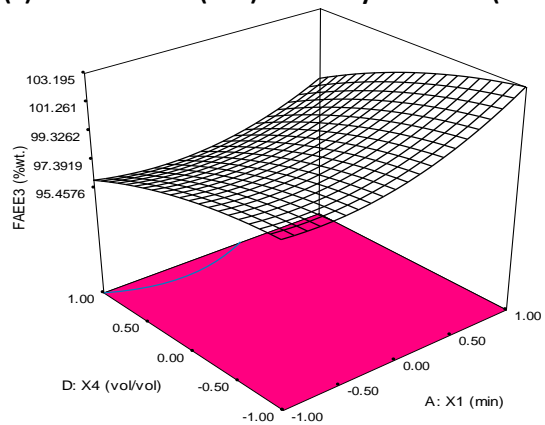
Std. Dev.	0.12	R-Squared	99.98%
Mean	93.45	Adj R-Squared	99.92%
C.V.	0.0056	Pred R-Squared	99.97%
PRESS	0.0043	Adeq Precision	127.523



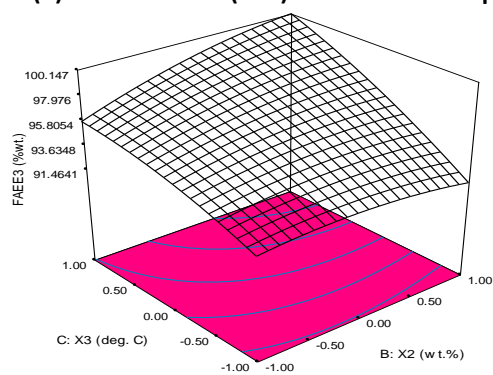
(a) Reaction time (min) Vs. Catalyst amount (wt. %)



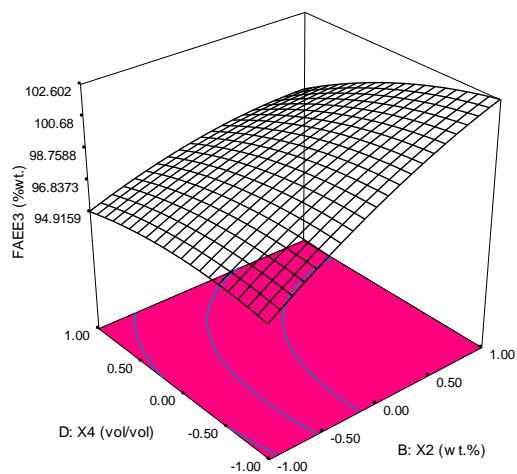
(b) Reaction time (min) Vs. Reaction temperature (deg. C)



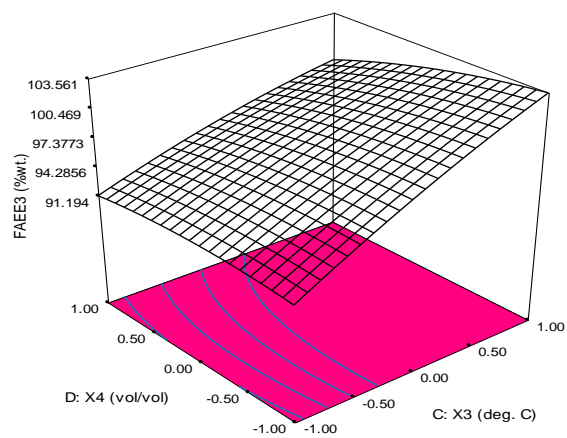
(c) Reaction time (min) Vs. EtOH/OMR (vol/vol)



(d) Catalyst amount (wt. %) Vs. Reaction temperature (deg. C)



(e) Catalyst amount (wt. %) Vs. EtoH/OMR (vol/vol)



(f) EtoH/OMR (vol/vol) Vs. Reaction temperature (deg. C)

Fig. 1(a-f): Three dimensional plots

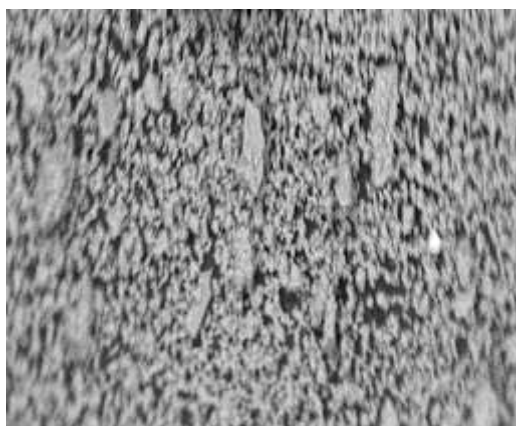


Fig. 2a: SEM images of calcined catalyst

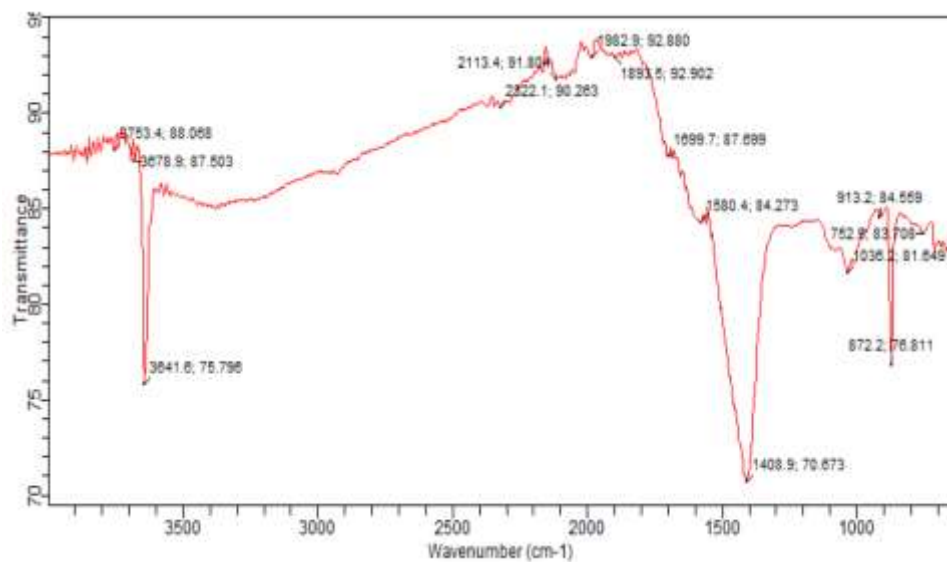


Fig. 2b: FTIR spectral analysis of the catalyst

Table 4: BET and XRD analysis of the catalyst

Catalysts	β (m ² /g)	λ (cm ³ /g)	CaO (%)	BS ($\mu\text{mole.g}^{-1}$)		TBS	BSD ($\mu\text{mole/m}^2$)	FAEE (%wt.)	CA (wt.%)
				400<BS<650	>650				
SFCTCPH	1.10	0.0030	87.65	22	174	196	178.18	98.20	2.50

β = Surface area, λ = Pore volume, BS = Basic site, TBS = Total basic site, BSD = Basic site density, GD = Green diesel, CA = Catalyst amount

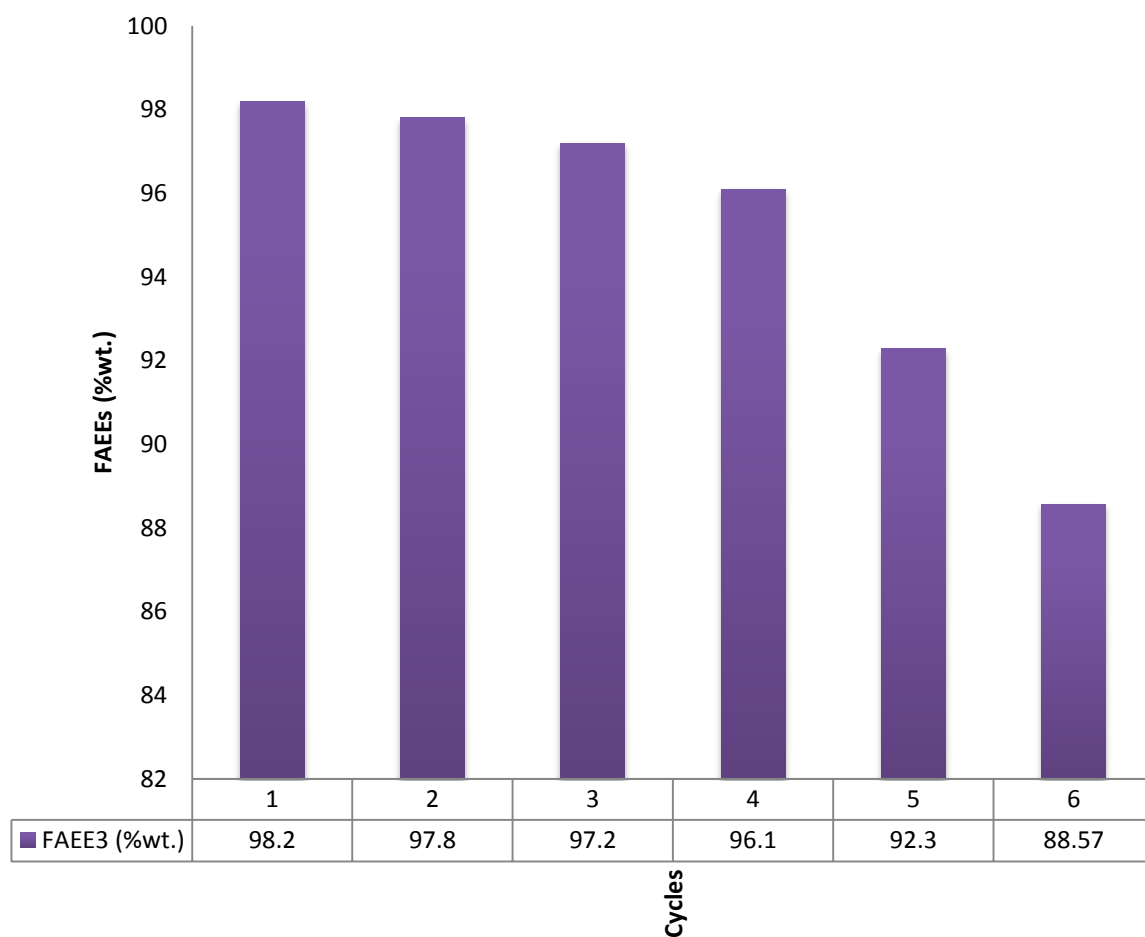


Fig. 3: Plots of results of catalysts reusability test

Table 5: Qualities of the produced FAEE

Parameter	BTO ₆₀	FAEE3	[2]	[3]
Colour@ 27 °C	Brownish-yellow	Light yellowish	-	-
State @ room temp	Liquid	Liquid	Liquid	Liquid

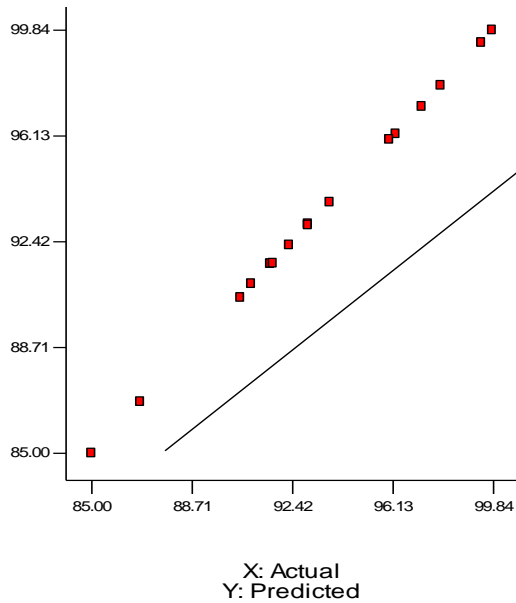
Specific gravity	0.902	0.864	-	860-900
Viscosity @ 40 °C/ (mm ² /s)	22.30	2.78	1.9-6.0	3.5-5.0
Moisture content (%)	0.02	<0.01	<0.03	0.02
%FFA (as oleic acid)	0.1745	0.018	0.40 max	0.25 max
Acid value (mg KOH/g oil)	0.249	0.036	0.80 max	0.50 max
Iodine value (g I ₂ /100g oil)	58.88	53.62	ND	120 max
Saponification value (mg KOH/g oil)	180.00	172.22	236.66-253.04	ND
Peroxide value (meq O ₂ /kg oil)	12.65	8.60	ND	12.85
HHV (MJ/kg)	41.17	41.52	ND	ND
Cetane number	63.39	65.92	57 min	51 min
API gravity	22.30	32.27	30-42	ND
Diesel index	49.50	52.04	50.4 min	ND

ND = Not Determine

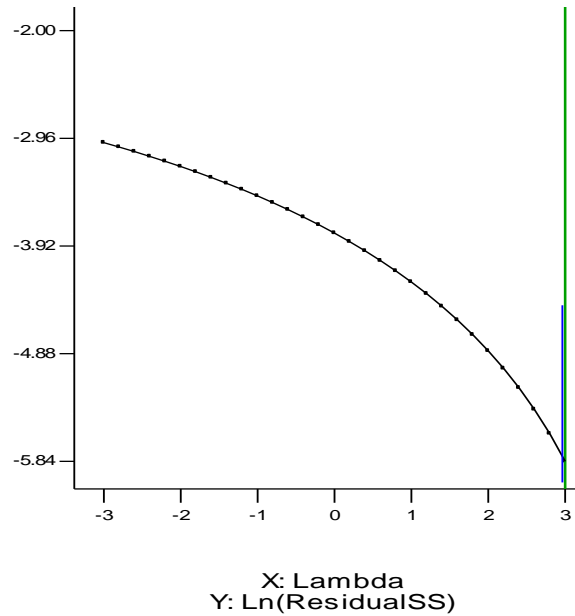
Table 7: Comparing this study with reported literature studies

Blended Oil	Blending ratio (vol/vol)	Catalysts	Calcination temperature and duration	% CaO/KOH conversion	Catalyst analysis	% Biodiesel yield	References
Waste cooking oil	-	Ripe and unripe Plantain peels	500 °C for 4 h	KOH = 47.67%	XRD, SEM, BET, and FTIR	97.96	[7]
<i>Jatropha curcus</i> + <i>Heavea brasiliensis</i> + <i>Elais guineensis</i> oils	33:33:34	Chicken foot, Cat fish bones, and mixed	1000 °C for 3 h	CaO = 99.84%	SEM, EDX-ray, FTIR and BET	97.25	[8]

<i>Calophyllum inophyllum</i> -waste cooking oil	50:50	Donax deltoids shells	105 °C for 24 h	CaO = 70.87%	XRD, SEM, BET, and FTIR	96.50	[9]
Waste cooking oil (WCO)	-	Ca(NO ₃).4H ₂ O	900 °C for 3 h	CaO=99.92 %	XRD, SEM, BET, and FTIR	99.19%	[10]
Waste + pure vegetable oil	-	Banana peel	700 °C for 4 h	KOH		94 to 97%	[11]
Beef Tallow blend + Waste used vegetable oil	60:40	<i>Theobroma cacao</i> pod husks		CaO	XRD, SEM, BET, and FTIR		THIS STUDY
		<i>Submerged fermented calcined</i>	750 °C for 4 h	87.65%		99.64%	



Predicted against Actual



Box-Cox Plot for Power Transformation