Validation of Optimal Conditions of the Functional Properties of Rubber Seed Oil-Derived Biodiesel

Ezeakacha Samuel Ikechukwu*, Okoro Gideon Onyekachi**

*Department of Chemical Engineering, Nnamdi Azikiwe University Awka Nigeria,

**Department of Agricultural and Bioresources Engineering, University of Nigeria Nsukka

gideononyekachi1990@gmail.com samuelezeakacha@gmail.com

‡ Corresponding Author; Ezeakacha Samuel Ikechukwu, Nnamdi Azikiwe University Awka Nigeria, Tel: +2347032739911, samuelezeakacha@gmail.com

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Abstract- As a result of cost, environmental impact and fear of sustainability of petroleum products, various alternatives for energy have been sourced out, of which biodiesel is seen as the closest. Rubber seed oil has been a viable source for biodiesel production because it is not edible. This oil was used in this work to produce biodiesel and the functional properties which are the cetane number, kinematic viscosity and yield were optimized. Response surface methodology is one of the tools used for the simulation and optimization of biodiesel production process. Thirty (30) experiments were carried out in the lab using experimental process design for the trans-esterification process via CCD. A parametric study of the process parameters involved in the trans-esterification reaction showed that the output responses which were yield, kinematic viscosity and cetane number had greater dependence on the methanol to oil ratio, reaction time and reaction temperature than on catalyst concentration. Optimal prediction of the output responses using numerical optimization techniques were obtained at a reaction time of 151 min, reaction temperature of 48.98 or 49℃ , methanol to oil ratio of 8.27:1 and catalyst concentration of 1.2%. Validation experiments carried out in the laboratory using the optimal parameters showed that the predicted and actual values gotten from the experiment were in close interaction. A comprehensive analysis was carried out on the rubber oil derived biodiesel produced in the laboratory for its physiochemical and fuel properties (acid value, iodine value, peroxide value, viscosity, saponification value. Results revealed that the biodiesel obtained can be used to supplement petro diesel by blending in suitable ratios.

Keywords Biodiesel, Rubber seed oil, Temperature, Optimization, Time, Concentration, Ratio, Yield, Kinematic viscosity, Cetane number

1. Introduction

The availability and sustainability of energy have been a challenging problem since the industrial revolution. Economically, a shortfall in the supply of energy resources is termed as energy crisis[1], as a result of over dependence on the liquid and solid fossil fuels. The consumption rates of these fossil fuels are faster than the production, therefore to find an alternative for the use of fossil fuels, many renewable energy sources have been tried. Out of these many sources of renewable energy available, biodiesel is a feasible alternative[2]. Biodiesel is defined as a liquid fuel which is made up of fatty acid alkyl ester of the long chain fatty acid, derived from the vegetable oil and animal fat [1, 3]. Biodiesel as an alternative source is reported to show many advantages as compared to conventional (petroleum) diesel and these include, their availability from renewable feedstocks, superior lubrication property, biodegradability, lesser toxicity (depends on nature of feedstock), displacement of imported petroleum products, higher flash point, and a reduction in most of the exhaust emissions[4, 5]. Moreover, biodiesel is considered as green fuel because it does not contain any Sulphur, aromatic hydrocarbons and metals [6]. The production of biodiesel is achieved through trans-esterification or alcoholysis, which is used to reduce the high viscosity of triglyceride[7]. Most of the work done on the production of biodiesel used vegetable oils such as coconut oil, palm oil,

soybean, corn, cotton seed etc. However the above oils listed above are edible oils and hence will cause shortages in food supply thereby increasing the cost of food, therefore the need to for the production of biodiesel from non-edible oil sources [1, 8].

Rubber tree (*Hevea brasiliensis*) is a tall deciduous tree growing to a height of up to 43 m (141 ft) in the wild, but cultivated trees are usually much smaller because drawing off the latex restricts the growth of the tree. Rubber tree is the source of latex that is a feedstock for the production of rubber tyres used on motor vehicles, motor cycles and bicycles. It also produces seeds which are usually allowed to drop to the ground to decay despite having a yield of seeds per annum estimated at 100-150 kg/ha [9] and seed oil content of 35 - 40% [10]. It is not edible and so does not compete with the demand from food industry, although it is eaten by cows in Nigeria, not minding the fact that it contains cyanogenic glycosides which will release prussic acid in acidic condition. The oil is unsaturated and semidry and can hence be used in the manufacture of paint, soap, alkyd resin and wood polish [10]. The potential for using it as a feed stock for biodiesel (methyl ester) production has been investigated severally by [10] and [11]. The characterization of rubber seed oil and its biodiesel have also been undertaken by [1], but limited to the oil and biodiesel production. Various works have been carried out on the extraction and esterification of the Rubber seed oil, but these works were based on a one factor at a time approach (OFAT). The parametric study of the properties of Rubber seed derived biodiesel to suit or to be a successful alternative to petroleum diesel was carried out in this study, using response surface methodology (RSM) to optimize the process parameters[8, 12]. The central composite design was also employed for analyzing the experiment, and the results obtained were compared with previous research works. The aim of this study is to find the optimum condition and parametric values for the production of biodiesel oil with a relatively higher cetane number and good yield from rubber seed oil.

2. Methodology

a. Materials

The rubber seed oil being the basic raw material used in the production of biodiesel was obtained from Rubber research institute Benin City, Nigeria. Laboratory grade methanol of 99% purity, was purchased from Onitsha main market Anambra State, Nigeria. Sodium hydroxide pellets of 96% purity which was employed as the heterogeneous catalyst and distilled water ~~used~~ was provided by the spring board Laboratory.

b. Physiochemical analysis of rubber seed oil

The fuel and physiochemical properties of the rubber seed oil like the iodine value, the saponification value, the peroxide and acid values, the dynamic and kinematic viscosities, the pour and cloud points, and the flash points were determined following ASTM, EN and AOCS methods[13, 17].

c. Esterification of Rubber seed oil

The oil to be used for biodiesel production was acid esterified with methanol according to a 3: 1 methanol to oil ratio using three moles (3mols) of sulphuric acid (H_2SO_4) as a catalyst. The reaction was carried out for a period of 1 hour after which the mixture was allowed to stand in a separating flask for 5 hours [1, 11, 18-20].

d. Transesterification of the pre-treated Rubber seed oil

Thirty millilitres (30ml) of the esterified oil was reacted with varying ratios of methanol using sodium hydroxide pellets of varying catalyst concentration to transform the glyceride portion into biodiesel [17,]. The reaction mixture was carried out under different reaction times and temperatures following the design template produced using design expert. After the reaction time elapsed the biodiesel mixture was allowed to rest. The biodiesel samples were divided into five, then analyzed. The result of the analysis is as tabulated in Table 2

e. *Separation and purification of the Biodiesel*

After 5 hours the reaction mixture had separated into two distinct layers giving the glycerol below and the biodiesel on top. The biodiesel was run out from the separating flask and washed 3 times with 100ml of hot distilled water [17, 21-23]. The resulting mixture gave a pure biodiesel layer on top leaving the water below. The neat biodiesel sample was dried in a desiccator at a temperature of 110^{o}C for 30 minutes until all the water had evaporated.

f. Characterization of Biodiesel

The density of was obtained with a mass balance, the mass balance was tabulated and divided using the same volume of the biodiesel measured, in accordance with ASTM D 4052 testing method. The kinematic viscosity was determined using Herzog GmbH MP – 480, with the kinematic viscosity calculated using equation 1 according to ASTM D 2500 method [19, 24-27].

$$K.V = \frac{Calibration\ constant(mm)^2}{mean\ time\ of\ flow(s)} \quad \text{Eqn 1}$$

K.V = kinematic viscosity (mm^2/s)

The FAME content of the biodiesel was determined by washing 2g of biodiesel using 50ml of n-hexane, 0.5g of sodium silicate and 1g of magnesium trisilicate powder. The mixture was allowed to stand for 7minutes and analyzed using gas chromatography. The Cetane number of the biodiesel was calculated using equation 2.

$$Cetane\ number = 4.63 + \frac{5458}{SV} - 0.225IV \quad \text{Eqn 2.}$$

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

The flash point was determined using the Kehler Model K-16270 according to ASTM D6751. The cloud and pour point were determined using a cloud point meter equipped with a waveguide sensor according to the ASTM D 2500 method. The iodine value was determined using the Wijs reagent[11, 19, 26].

Table 1: Proximate analysis of rubber seed oil

Property	Value
Acid value (%)	77.28
FFA (%)	38.64
Saponification val.(mg/KOH)	95.37
Iodine value	104.48
Viscosity (cP)	1029
pH value	6.10
Density (g/ml)	0.912
Specific gravity	0.916

The result of the proximate analysis of the rubber seed oil is as shown in Table 1.

It can be seen from Table 3 that the values of the five biodiesel samples are higher than the ASTM standard. Also as reported in the methodology, the cetane number was determined using saponification and the iodine value. The cetane number of RB5 was seen to be above minimum as postulated by ASTM D975.

Table 2: Independent variables and levels used for CCD

S/N	Independent variables	Coded symbols	Range and Levels				
			-α	-1	0	+1	+α
1	Reaction temperature	A	40	45	50	55	60
2	Reaction time	B	120	150	180	210	240
3	Catalyst concentration	C	0.8	1	1.2	1.4	1.6
4	Oil-methanol ratio	D	3	6	9	12	15

g. Experimental design and statistical analysis

For this research work, the input variables that were monitored in order to obtain the required responses such as yield, cetane number and kinematic viscosity were;

- Reaction temperature – Factor A
- Reaction time – Factor B
- Catalyst concentration – Factor C
- Oil to Methanol ratio – Factor D

Using the Central Composite Design (CCD), a design of experiment template was generated with thirty runs comprising of various permutations of the variables previously mentioned as can be seen in Table 4. Upon completion of experiment and characterization, the values for the yield, kinematic viscosity and cetane number were calculated and tabulated. The design model was generated for both actual factors and coded factors.

The equations in terms of actual factors were determined as

$$Yield = 186.25 - 1.232A - 0.256B - 4 \times 10^{-14}C - 2.06D \quad \text{Eqn (2)}$$

$$Cetane\ Number = -37.6896 + 0.968A + 1.56841B + 22.2718C - 20.3509D - 0.03842AB + 0.010625AC + 0.424958AD - 0.000521BC + 0.00134BD - 0.005208CD + 0.018603A\text{^}2 + 0.000203B\text{^}2 - 0.023437C\text{^}2 - 0.000104D\text{^}2 \quad \text{Eqn (3)}$$

$$Kinematic\ Viscosity = 23.623 - 0.7845A + 0.004521B + 2.26771C - 0.77D + 0.000413AB + 0.188125AC + 0.057792AD + 0.004688BC - 0.001924BD - 1.49896CD \quad \text{Eqn (4)}$$

Table 3: Proximate Analysis of Rubber seed oil biodiesel produced

Property	ASTM D975	RB1	RB2	RB3	RB4	RB5
Acid value (mgKOH/g)	0.5	0.64	0.74	0.78	0.76	0.67
FFA(%)	-	0.32	0.37	0.39	0.38	0.33
Saponification value (mg/KOH)	-	633.93	476.85	412.34	373.07	162.69
Iodine value	160max	87.98	109.13	112.10	114.63	112.94
Cetane number	47min	35.11	33.19	34.31	35.14	54.4
Kinematic viscosity (mm^2/s)	1.9-6	2.05	2.73	3.65	3.71	1.67
pH value	-	5.19	6.18	6.81	7.33	6.89
Density(g/ml)	0.86-0.9	0.847	0.903	0.897	0.877	0.809
Specific gravity	-	0.826	0.907	0.901	0.881	0.789
Flash point(^oC)	93min	217	226	271	290	-

Table 4: Design of Experiment template in Actual form

Run	Factor A	Factor B	Factor C	Factor D	Yield (%)	Kinematic viscosity (mm^2/s)	Cetane Number
1	45	210	1	6	64.69	4.51	34.6
2	55	210	1	6	52.37	2.82	7.26
3	50	180	1.2	9	60.03	3.72	36.89
4	55	210	1.4	12	40.01	5.31	36.09
5	40	180	1.2	9	72.35	3.8	41.22
6	45	150	1	12	69.56	2.73	33.19
7	45	210	1.4	12	52.33	0.8	37.89
8	50	240	1.2	9	44.67	4.5	21.02
9	55	150	1	6	67.73	2.05	35.11
10	50	180	1.2	9	58.16	3.65	34.31
11	55	210	1.4	6	52.37	5.41	16.33
12	50	120	1.2	9	75.39	5.3	53.19
13	55	210	1	12	40.01	5.25	27.04
14	45	150	1.4	6	80.05	4.8	48.43
15	45	150	1.4	12	67.69	1.12	42.21
16	45	150	1	6	80.05	2.27	39.39
17	50	180	1.2	9	60.03	3.72	36.89
18	55	150	1.4	12	55.37	3.14	63.47
19	45	210	1	12	52.33	5.3	28.88
20	45	210	1.4	6	64.69	5.46	43.62
21	50	180	0.8	9	60.03	3.65	27.33
22	50	180	1.6	9	60.03	2.44	45.41
23	50	180	1.2	9	60.03	3.72	36.89
24	50	180	1.2	9	60.03	3.75	36.89
25	55	150	1.4	6	67.73	2.05	44.18
26	50	180	1.2	3	72.39	4.03	29.59
27	55	150	1	12	53.5	5.41	54.4
28	50	180	1.2	15	47.67	3.27	43.15
29	60	180	1.2	9	49.58	3.71	35.14

30	50	180	1.2	9	60.03	3.75	36.37

Table 5: Results gotten from Laboratory Experiment

Run	Factor A	Factor B	Factor C	Factor D	Yield (%)	Kinematic viscosity (mm^2/s)	Cetane Number
1	45	210	1	6	63.92	3.81	33.9
2	55	210	1	6	53.01	2.12	6.56
3	50	180	1.2	9	61.12	3.02	36.19
4	55	210	1.4	12	40.93	4.61	35.39
5	40	180	1.2	9	72.54	3.13	40.55
6	45	150	1	12	70.01	2.06	32.52
7	45	210	1.4	12	54.91	0.13	37.22
8	50	240	1.2	9	43.06	3.83	20.35
9	55	150	1	6	67.08	1.38	34.44
10	50	180	1.2	9	57.65	2.98	33.64
11	55	210	1.4	6	53.01	4.74	15.66
12	50	120	1.2	9	74.46	4.63	52.52
13	55	210	1	12	40.94	4.91	26.7
14	45	150	1.4	6	81.09	4.46	48.09
15	45	150	1.4	12	68.92	0.78	41.87
16	45	150	1	6	80.94	1.93	39.05
17	50	180	1.2	9	60.39	3.38	36.55
18	55	150	1.4	12	54.73	2.47	62.8
19	45	210	1	12	53.71	4.63	28.21
20	45	210	1.4	6	65.13	4.79	42.95
21	50	180	0.8	9	59.76	3.31	26.99
22	50	180	1.6	9	59.74	1.77	44.74
23	50	180	1.2	9	59.76	3.38	36.55
24	50	180	1.2	9	59.76	3.41	36.55
25	55	150	1.4	6	68.04	1.71	43.84
26	50	180	1.2	3	72.12	3.69	29.25
27	55	150	1	12	54.05	5.07	54.06
28	50	180	1.2	15	48.15	2.6	42.48
29	60	180	1.2	9	49.97	3.5	34.93
30	50	180	1.2	9	60.34	3.05	35.67

3.0. Results and Discussion

3.1. Rubber seed oil analysis

The proximate analysis of the rubber seed oil was carried out, and the results were given in Table 1. And comparing with the result gotten from [1], it can be seen that the iodine value gotten from this research is close to what they obtained.

3.2. Acid esterification

As designed in Table 4, the transesterification was carried out, and the response factors, which are yield, kinematic viscosity and cetane number were calculated. ANOVA was carried out on each of the response factors to provide a statistical analysis to ascertain the degree of significance of a model equation resulting from the optimization. A plot of all the factors and their effect on each of the response factors were made and shown in Figures

3.3. ANOVA analysis

Statistical analysis (ANOVA) was carried out on the data gotten from each Response variables, to ascertain how suitable and significant the independent variables are in determining them as can be seen in Tables 5, 6 and 7. P-values less than 0.05 indicate model terms are statistically significant to the response factors, P-values greater than 0.05 show that the model terms are not statistically significant. As seen from Table 7, the

model F-value of 1449.00 implies that the model is significant, and there is only 0.01% chance that the F-value this large could occur due to noise. In this case, since the p-values of factors A, B, C, and D are less than 0.0500, A, B, C, D are significant model terms, suggesting that the concentration of the catalyst has minimal effect on the yield of biodiesel. The lack of fit F-value of 0.95 suggests that the lack of fit is not statistically significant relative to pure error.

In Table 6, The Model F-value of 716.72 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case A, B, C, D, AB, AD, A^2 are significant model terms. The Lack of Fit F-value of 0.00 implies the Lack of Fit is not significant relative to the pure error. There is a 100.00% chance that a Lack of Fit F-value this large could occur due to noise. Non-significant lack of fit is good since we want the model to fit.

The Model F-value of 3.72 in Table 8 shows that the model is significant. There is only a 0.67% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case B, AD, CD are significant model terms. The Lack of Fit F-value of 867.60 implies the Lack of Fit is significant. There is only a 0.01% chance that a Lack of Fit F-value this large could occur due to noise. Significant lack of fit is bad since we want the model to fit.

Table 6: ANOVA for Quadratic Model (cetane number)

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	3562.25	14	254.45	716.72	< 0.0001	**Significant**
A-temp	55.48	1	55.48	156.27	< 0.0001	
B-time	1552.20	1	1552.20	4372.20	< 0.0001	
C-conc	490.60	1	490.60	1381.91	< 0.0001	
D-ratio	275.88	1	275.88	777.09	< 0.0001	
AB	531.42	1	531.42	1496.88	< 0.0001	
AC	0.0018	1	0.0018	0.0051	0.9441	
AD	650.12	1	650.12	1831.25	< 0.0001	
BC	0.0002	1	0.0002	0.0004	0.9835	
BD	0.2328	1	0.2328	0.6558	0.4307	
CD	0.0002	1	0.0002	0.0004	0.9835	
A^2	5.59	1	5.59	15.75	0.0012	
B^2	0.9167	1	0.9167	2.58	0.1289	
C^2	0.0000	1	0.0000	0.0001	0.9935	
D^2	0.0000	1	0.0000	0.0001	0.9935	
Residual	5.33	15	0.3550			
Lack of Fit	0.0001	10	0.0000	0.0000	1.0000	**not significant**
Pure Error	5.33	5	1.07			
Cor Total	3567.58	29				

Table 7: ANOVA table for Linear model (yield)

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	3242.89	4	810.72	1449.00	< 0.0001	**Significant**
A-temp	910.69	1	910.69	1627.68	< 0.0001	
B-time	1415.58	1	1415.58	2530.06	< 0.0001	
C-conc	0.0000	1	0.0000	0.0000	1.0000	
D-ratio	916.62	1	916.62	1638.27	< 0.0001	
Residual	13.99	25	0.5595			
Lack of Fit	11.07	20	0.5537	0.9500	0.5849	**not significant**
Pure Error	2.91	5	0.5828			

Cor Total	3256.88	29				

Table 8: ANOVA for Two Factor Interaction (2FI) model (kinematic viscosity)

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	31.81	10	3.18	3.72	0.0067	**Significant**
A-temp	0.7597	1	0.7597	0.8887	0.3577	
B-time	3.91	1	3.91	4.58	0.0456	
C-conc	0.9087	1	0.9087	1.06	0.3155	
D-ratio	0.1395	1	0.1395	0.1632	0.6907	
AB	0.0613	1	0.0613	0.0717	0.7918	
AC	0.5663	1	0.5663	0.6624	0.4258	
AD	12.02	1	12.02	14.06	0.0014	
BC	0.0127	1	0.0127	0.0148	0.9044	
BD	0.4796	1	0.4796	0.5610	0.4630	
CD	12.94	1	12.94	15.14	0.0010	
Residual	16.24	19	0.8549			
Lack of Fit	16.24	14	1.16	867.60	< 0.0001	**Significant**
Pure Error	0.0067	5	0.0013			
Cor Total	48.05	29				

3.4. Response Surface Plots

The 3D plots for the output responses were plotted, the plots showed the effect of reaction time, temperature, catalyst concentration and oil to methanol ratio on the yield, cetane number and kinematic viscosity. The plots of actual against the predicted values are also shown in Figure 7, to depict the closeness to the actual values that the predicted ones obtained from the model are.

3.4.1. Response plots of yield

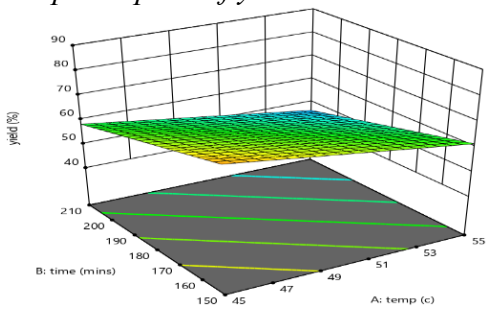


Figure 1: Effect of reaction time and temperature on yield

The plots shown in Figures 1, 2, and 3 shows the response surface of yield to increase or decrease in the reaction time, catalyst concentration, oil-methanol ratio and reaction temperature. The outward rise in the shape of the surface indicates that the optimum yield value is affected by the various levels of the input variables. However, the plots including catalyst concentration have a horizontal contour rather than adjacent slopes. This

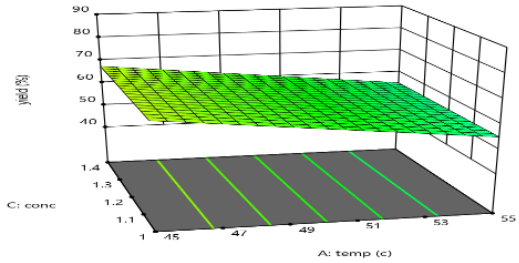


Figure 2: Effect of Concentration and temperature on yield

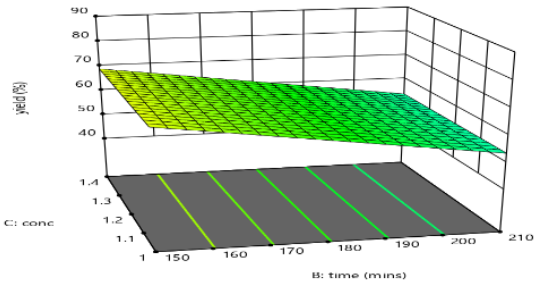


Figure 3: Effect of catalyst concentration and reaction time on yield

indicates that the effect of catalyst concentration on the yield of the biodiesel is minimal if not negligible. The contour graph gives the range of the input variables at which optimum yield will occur.

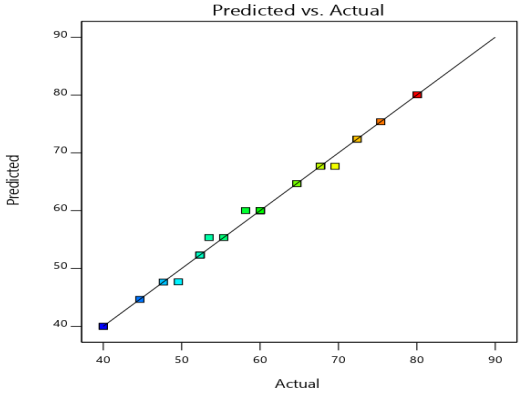


Figure 4: Plot of predicted vs actual yield

The conformity of the actual values to the predicted values from the model can be seen from the plot of predicted against actual yield in Figure 4, with an R^2 value of 0.9957. The lack of fit is seen to be insignificant. Therefore, the model is suitable for predicting the yield of biodiesel with a relatively higher cetane number from rubber oil under similar input variables.

3.4.2. Response plots of Cetane number

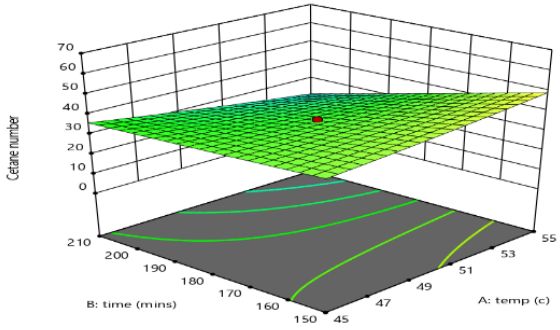


Figure 5: Effect of reaction time and temperature on Cetane number

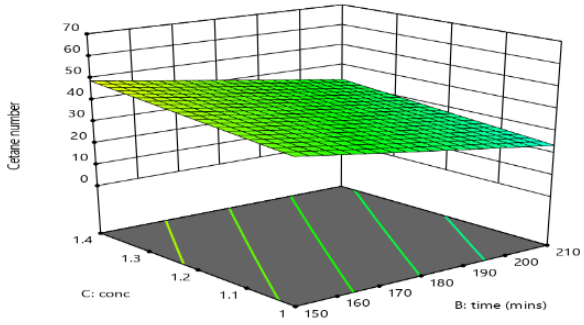


Figure 6: Effect of reaction time and temperature on Cetane number

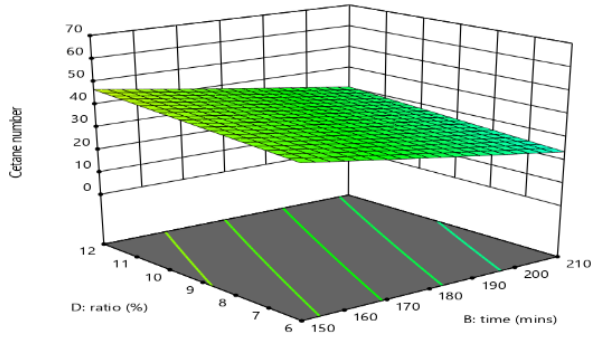


Figure 7: Effect of ratio and reaction time on Cetane number

The various response surfaces for reaction time, temperature, methanol to oil ratio and catalyst concentration is shown in the 3D plots for cetane number in figures 5, 6 and 7. Unlike in the yield plots where the contours are linear, the cetane number contours are curved in conformity with the quadratic model which was predicted. The plots show the range of the input variables at which an optimum cetane number is likely to be found. Unlike the yield model, cetane number is dependent on catalyst concentration, however this dependency is also minimal.

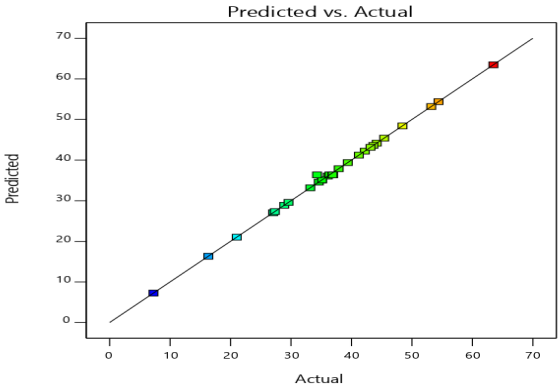


Figure 8: plot of predicted vs actual cetane number

Figure 8 shows the conformity of the predicted values of cetane number done by the simulation software to the actual number, with an R^2 value of 0.9985. The lack of fit is seen to be insignificant. Hence the cetane number model generated can be used for predicting the values of cetane number at various levels of the input variables.

3.4.3. Response plots of Kinematic viscosity

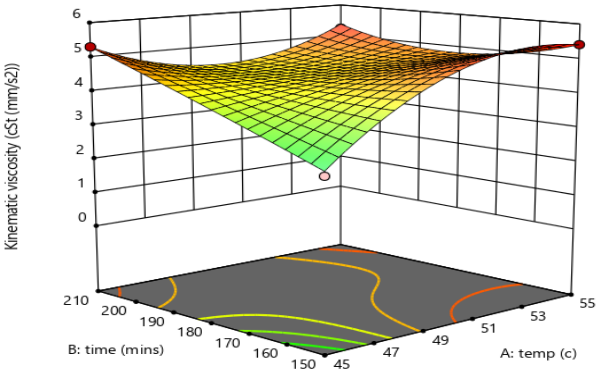


Figure 9: Effect of reaction time and temperature on kinematic viscosity

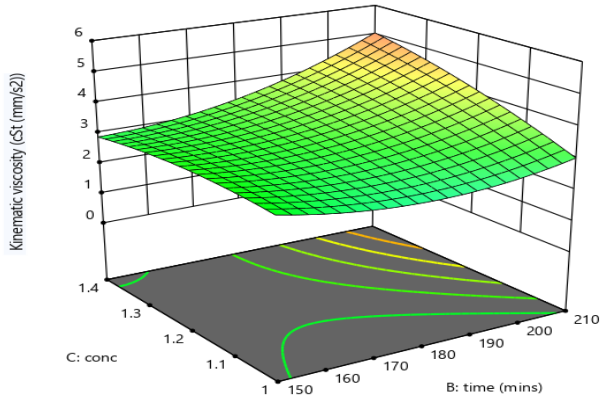


Figure 10: Effect of catalyst concentration and reaction time on kinematic viscosity

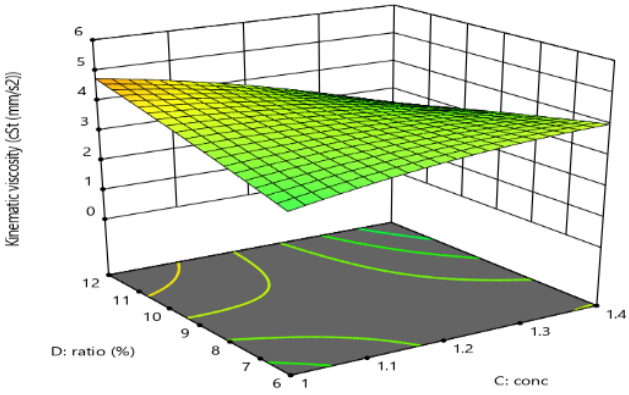


Figure 11: Effect of ratio and catalyst concentration on kinematic viscosity

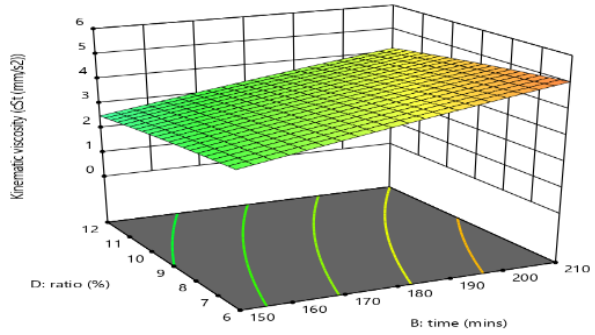
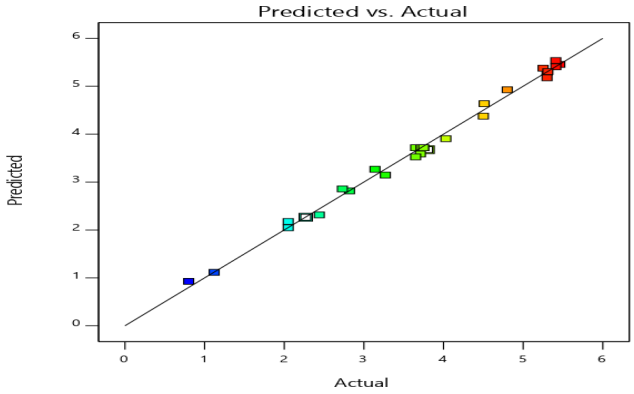


Figure 12: Effect of ratio and time on kinematic viscosity

The 3D plots for kinematic viscosity above shows its various response surfaces for reaction time, temperature, methanol to oil ratio and catalyst concentration. Unlike in the yield plot, the surfaces are curved just like the cetane number surfaces in conformity with the two factor interaction (2FI) model which was predicted. The plots show the range of the input variables at which an optimum kinematic viscosity is likely to be found. Unlike the yield model, kinematic viscosity is dependent on catalyst concentration.

Figure 13: plot of predicted vs actual kinematic viscosity

Figure 13 shows the lack of conformity between the actual and predicted values of kinematic viscosity, with an R^2 value of 0.7465. This plot concurs with the ANOVA report which stated the significance of the lack of fit. This implies that the model may not be sufficient for the prediction of kinematic viscosity values at various levels of the input variables.



4.0. Optimization

The optimization of the process was done using the RSM tool of Design Expert software version 11. The constraints were set such that the yield was maximized, cetane number was maximized and a range for kinematic viscosity within the allowable limits by ASTM standards. The table showing the various optimal runs is shown in Table 9, with Table 10 showing the Set constraints for Optimization.

From Table 9, the best search result for the optimum results is found to be the second search with cetane number of 44.8 and yield of 70.1% and kinematic viscosity of 4.074. This search was selected because the most important functional property taken into consideration is the cetane number. Hence the selection of a run with the best cetane number at a relatively high yield and a kinematic viscosity within the stipulated limits. Table 10 shows the constraints which were applied into the software to obtain the optimization results.

The validation of the optimization result was carried out in the laboratory with 30 replications as can be seen in Table 5, with the conditions given by

the software for optimum at temperature of 48.98^{0}C, catalyst concentration of 1.28%, methanol to oil ratio of 8.27:1 and reaction time of 151.255mins. The results obtained from the Laboratory were a kinematic viscosity value of 4.102, a yield of 69.3% and a cetane number of 44.25 which when compared are in close proximity to that predicted by the software.

Table 9: Optimization report using RSM

Number	Temp	Time	conc	ratio	Yield	Kinematic viscosity	Cetane number	Desirability	
1	47.794	153.013	1.277	8.174	71.358	4.003	43.847	0.598	
2	**48.988**	**151.255**	**1.283**	**8.277**	**70.124**	**4.074**	**44.862**	**0.594**	**Selected**
3	48.966	150.001	1.241	8.272	70.484	4.131	44.201	0.593	
4	50.127	150.000	1.262	8.526	68.530	4.099	45.571	0.587	
5	50.586	150.000	1.165	8.553	67.908	4.219	43.720	0.556	
6	52.304	150.000	1.234	8.693	65.503	3.963	46.776	0.554	
7	51.437	150.000	1.081	9.069	65.797	4.371	43.273	0.488	
8	45.038	196.072	1.120	6.778	66.605	4.556	37.461	0.270	

Table 10: Constraints set for optimization

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A:temp	is in range	45	55	1	1	3
B:time	is in range	150	210	1	1	3
C:conc	is in range	1	1.4	1	1	3
D:ratio	is in range	6	12	1	1	3
Yield	maximize	60	80.05	1	1	3
Kinematic viscosity	is in range	1.2	6	1	1	3
Cetane number	maximize	37	63.47	1	1	3
StdErr(Cetane number)	minimize	0.243248	0.455074	1	1	3

5.0. Conclusion

Rubber seed oil was successfully analyzed using physiochemical analysis and FFA profile. Biodiesel was successfully produced from rubber seed oil using a heterogeneous catalyst. From the study it was shown that yield, kinematic viscosity and cetane number have a greater dependence on temperature, time and methanol to oil ratio than on catalyst concentration. Maximum yield, cetane number and kinematic viscosity was obtained on different runs however none of them proved to be the optimum run. The optimum results for the production of biodiesel from rubber seed oil was obtained at 48.988^{o}C, 151.25 mins, 1.28wt % catalyst concentration and 8.27:1 methanol to oil ratio. From Table 10, it can be seen that row one has highest yield in the table, but the parameters in the second row was selected as the optimum parameter because our focus is a set of parameters that will give a good yield of biodiesel with a higher cetane number which is actually our main aim of

conducting the research. Analysis of biodiesel produced using the selected optimum run showed that the optimal prediction for rubber seed oil derived biodiesel is valid when compared to the works of [28][29][30] who obtained a biodiesel yield of 71%.

6.0 Recommendation

Based on the results and conclusion, the following recommendations are made

- Further research should be carried out on the production of biodiesel from rubber seed oil to determine if the yield and cetane number can be improved during production.
- To improve the accuracy of results obtained private laboratories should be used in further research work so as to avoid inconsistencies encountered in public laboratories.

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