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Effect of Process Parameters in Cracking of Palm Oil to Yield Oleochemicals

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Abstract- Palm oil was cracked for the production of oleochemicals. The factorial design (FFD) was used to obtain a quadratic model, consisting of factorial trials to estimate quadratic effects. To examine catalytic cracking of palm oil the combined effect of the three different factors (independent variables): temperature, time and catalyst weight were studied on the yield of oleochemicals production and a model was derived from a full factorial designs of 3-level 3-factors design of experiment. For thermal cracking process (i.e. without Catalyst), full factorial designs of 3-level 2-factors design of experiment was used. Clay was used as the catalyst in the catalytic phase and analysis of variance, ANOVA was carried out to determine the adequacy of the obtained models. The ANOVA showed that the model was able to predict both thermal and catalytic cracking processes and there is an interactive effect between the process parameters only for catalytic cracking.

Keywords- *factorial design, ANOVA analysis, oleochemicals, palm oil, clay, catalytic and thermal cracking*

I. INTRODUCTION

One of the alternative fuels currently being studied is biofuels and chemical intermediates (Oleochemicals) obtained from vegetable oil. Liquid biofuel obtained from vegetable oil, is renewable and also free of nitrogen and sulphur compound as compared with fossil fuel. Among all of the Vegetable oils, palm oil is one of the vegetable oil that has the greatest possibility to be used in bio fuel production because of its abundance in nature [1,2]. Oleochemicals are chemicals derived from oils and fats. They are analogous to petrochemicals which are chemicals derived from petroleum. Oleochemicals are derivatives based on C_{12}-C_{14} and C_{16}-C_{18} chain lengths having a variety of uses. Tallow, palm and coconut oils have been the traditional raw materials used for the production of C_{16}-C_{18} and C_{12}-C_{14} chain lengths respectively [3,4,5]. The hydrolysis or alcoholysis of oils and fats formed the basis of the Oleochemicals industry. The five basic Oleochemicals are Fatty acids, Fatty Methyl esters and Ethyl esters, fatty alcohol, fatty nitrogen compounds and glycerol [6]. The process of derivation or obtaining these chemical intermediates from palm oil requires high temperature pyrolysis, alcoholysis, gasification or destructive distillation in the presence of a catalyst. Activated clay has been used extensively for over 60 years as catalyst for bleaching of palm oil [7,8].

In Nigeria, Clay minerals occur abundantly in the southern part of the country. The pore structure and the chemical nature usually determine the adsorption capacity or activity of the activated carbon as a catalyst. Cracking is the process whereby complex organic molecules such as kerogens or heavy hydrocarbons are broken down into simpler molecules such as light hydrocarbons, by the breaking carbon-carbon bonds in the precursors. The rate of cracking and the end products are strongly dependent on the temperature and pressure of catalysts. Other acid based catalysts also utilize acid treated montmorillonite clays [9]. For activated clay to have the desired properties, the temperature of carbonization must be well controlled. The temperature must be sufficiently high to dry and volatilize all non-carbon substances during carbonization.

When the cracking process employs the usage of catalyst, it is called catalytic cracking. This process needs less thermal energy and produces better quality products, depending on the catalyst used. Modern cracking uses homogenous and heterogeneous catalysts like zeolites. Zeolites are complex aluminosilicates, and are large lattices of aluminum, silicon and oxygen atoms caring a negative charge. They are, associated with positive ions such as sodium ions. Zeolites and other natural occurring carbons are chosen to give high percentages of hydrocarbons with 5 and 10 carbons, as well as 11 and 15 carbons. It also produces high proportions of branched alkanes and aromatic hydrocarbons like benzene. The zeolite catalyst has sites which can remove hydrogen from an alkane together with the two electrons which bound it to the carbon. The reaction temperatures are basically between 200-450^{o}C [10,11].

Thermal cracking employs the use of heat in the absence of catalyst. This is the simplest way to crack long chain hydrocarbons to shorter chain ones. High temperatures (typically in the range of 300^{o}C to 800^{o}C) and pressure (up to about 70 atmospheres) are used to break the large hydrocarbons into smaller ones. Thermal cracking gives mixtures of products containing high proportions of hydrocarbons with double bonds-Alkenes [5].

II. MATERIALS AND METHOD

A. *Raw material:*

The raw material was purchased from the market; the palm oil obtained underwent degumming in order to remove particulate matter in form of impurities, followed by dehydration for removal of water. It is then characterized to check for its physio-chemical properties before it is used for cracking and was compared with ASTM standards.

B. *Preparation of catalyst:*

The clay catalyst used as an adsorbent underwent carbonization at a temperature of 500^{O}C for 5 hours after which it was activated with sulphuric acid. Characterization of the clay sample is done to check for its physical and chemical properties, as well as the ability of the clay to act as adsorbent.

C. *Factorial Design – Central composite design (CCD)*

Factorial designs are very efficient for studying two or more factors. Myriad of researchers have applied this technique to solve different industrial problems [1, 2, 3, 4, 5, 6] and the effect of a factor can be described as the change in response produced by a change in the level of the factor. This is referred to as the main effect. In some experiments, it may be found that the difference in the response between levels of one factor is not the same at all levels of the other factors. This is referred to as an interaction effect between factors. Collectively, main effects and interaction effects are called the factorial effects [4]. A full factorial design can estimate all main effects and higher-order interactions. Another way to describe the concept of main effects and interaction effects for two-level designs is using a regression model. For example, suppose we have a full factorial design studying the six variables: A; B; C; D; E; and F with two levels for each drug. There are $2^6 = 64$ treatments or level combinations. These interactions and main effect can easily be visualized in the returned polynomial, quadratic or regression models using factorial design method. To obtain these regression models, response surface methodology based on careful design of experiment (DoE) is normally used.

Response surface methodology (RSM) is a collection of mathematical and statistical techniques for empirical model building. By careful design of *experiments*, the objective is to optimize a *response* (output variable) which is influenced by several *independent variables* (input variables). The applications of RSM to design optimization is aimed at reducing the cost of expensive analysis methods (e.g. finite element method or CFD analysis) and their associated numerical noise and allow the use of derivative-based algorithm. Vicente et al. (1996) have discussed the advantages of using RSM for design optimization applications. Generally, the structure of the relationship between the response and the independent variables is unknown. The first step in RSM is to find a suitable approximation to the true relationship. The most common forms are low-order polynomials (first or second-order). An important aspect of RSM is the *design of experiments* (Box and Draper, 2007), usually abbreviated as DoE. These strategies were originally developed for the model fitting of physical experiments, but can also be applied to numerical experiments. The objective of DoE is the selection of the points where the response should be evaluated. The approximation of the response function is called Response Surface Methodology.

$$y = f(x1, x2, \ldots, xq) + e. \quad (1)$$

If the response can be defined by a linear function of independent variables, then the approximating function is a **first-order model**. A first-order model with 2 independent variables can be expressed as:

$$y = \beta 0 + \beta 1 x1 + \beta 2\, x2 + e \quad (2)$$

If there is a curvature in the response surface, then a higher degree polynomial should be used. The approximating function with 2 variables is called a **second-order model**:

$$y = \beta 0 + \beta 1 x1 + \beta 2\, x2 + \beta 11 x_{11}{}^{2} + \beta 22\, x22^{2} + \beta 1{,}2\, x_1, x_2 + \epsilon \quad (3)$$

In general all *RSM* problems use either one or the mixture of the both of these models.

D. *Methodology*

To optimize the production of oleochemicals from palm oil cracking, factorial design (response surface methodology) was used to determine the optimum values of the process variables. The factorial design (FFD) was used to obtain a quadratic model, consisting of factorial trials to estimate quadratic effects. To examine catalytic cracking of palm oil the combined effect of the three different factors (independent variables): temperature, time and catalyst weight were studied on the yield of oleochemicals production and a model was derived from a factorial designs of 3-level 3-factors design of experiment; Whereas for thermal cracking (without Catalyst) factorial designs of 3-level 2-factors design of experiment was used to obtain the model. The experiments were performed in random order to avoid systematic error. The mathematical models relating the production of oleochemicals with the independent process variables was determined using statistical technique (surface response methodology) implemented in design expert 8.0. The adequacy of the above proposed models was tested using the Design Expert sequential model sum of squares and the model test statistics.

Using activated clay sample, the design plan as shown in Tables 1 and 2 were used to optimize the percentage yield of oleochemicals produced with activated clay serving as catalyst. The coded and uncoded values of the test variables were used to optimize the variables namely temperature, time and weight of catalyst for the catalytic cracking, then temperature and time only for the thermal cracking. The experimental values of oleochemicals produced are presented in Tables 1 and 2 The oleochemicals formed depends on the results showing a significant variation for each combination. The empirical relationships between oleochemicals and three variables in coded values obtained by using the statistical package Design-Expert 8.0 for determining the levels of factors which yield optimum oleochemicals were obtained. Finally, the ANOVA result is presented using the same surface response methodology implemented in design expert software.

III. RESULTS AND DISCUSSION

A. Statistical Analysis of Cracking Using Full Factorial Design (FFD)

TABLE I. DESIGN OF EXPERIMENT USING RESPONSE SURFACE METHODOLOGY: THERMAL CRACKING OF PALM OIL TEMPERATURE: 700 – 900^{O}C, TIME: 30 - 150 MINUTES

S/NO	TEMP (^{O}C)	TIME (MINS)	YIELD (%)	KINEMATIC VISCOSITY (Pa.S)	DENSITY (g/cm^3)	ACID VALUE (mg NaOH/g)
1	700	30	84	3.44	0.80	0.08
2	900	30	85	3.85	0.77	0.15
3	700	150	82	4.38	0.81	0.08
4	900	150	84	4.32	0.97	0.09
5	658.58	90	81	6.78	0.74	0.14
6	941.42	90	82	4.24	0.86	0.33
7	800	5.15	88	4.85	0.85	0.09
8	800	174.85	85	3.48	0.78	0.16
9	800	90	86	2.37	0.76	0.12
10	800	90	87	3.58	0.86	0.19
11	800	90	89	3.23	0.82	0.23
12	800	90	87	3.19	0.85	0.18
13	800	90	86	3.183	0.83	0.19

TABLE II. DESIGN OF EXPERIMENT USING RESPONSE SURFACE METHODOLOGY: CATALYTIC CRACKING OF PALM OIL. TEMPERATURE: 100 – 400^{0}C, TIME: 30 – 150 MINS, CATAYST: 10 – 50 GRAMS

S/NO	TEMP (^{O}C)	TIME (MINS)	CATALYST (GRAMS)	YIELD (%)	KINEMATIC VISCOSITY (Pa.S)	DENSITY (g/cm^3)	ACID VALUE (mg NaOH/g)
1	400	150	10	84	2.499	0.88	0.22
2	400	30	50	85	1.891	0.86	0.18
3	100	150	50	85	2.555	0.78	0.20
4	100	30	10	89	2.139	0.74	0.15
5	37.87	90	30	85	1.566	0.70	0.19
6	462.13	90	30	84	1.957	0.80	0.21
7	250	5.15	30	87	2.080	0.82	0.26
8	250	174.85	30	87	2.540	0.87	0.17
9	250	90	1.72	90	2.304	0.70	0.16
10	250	90	58.28	89	2.923	0.90	0.18
11	250	90	30	89	2.068	0.86	0.14
12	250	90	30	90	2.592	0.87	0.15
13	250	90	30	91	1.887	0.90	0.13
14	250	90	30	90	2.511	0.82	0.23
15	250	90	30	89	2.068	0.86	0.22

TABLE III. US AND INDIAN STANDARDS

Standards for Biodiesel	ASTM D-6751	IS 15607 : 2005
Density	0.86 – 0.90 g/cm^3	860 - 900 g / cm^3
Ester Content	Not Mentioned	96.5 %
Flash point (closed cup)	130°C min. (150°C average)	120°C
Water and sediment	0.050% by vol., max.	500 mg / Kg, max.
Kinematic viscosity at 40°C	1.9-6.0 mm^2/s	2.5-6.0 mm^2/s
Oxidation Stability	Not Mentioned	6 hours min, at 110°C
Cetane Number	47 min.	51 min.
Acid number, mg KOH/g	0.80 max	0.50 max
Methanol or Ethanol	Not Mentioned	0.2 % m/m, max
Free glycerin	0.020 % mass	0.020 % mass
Total glycerine (free glycerine and unconverted glycerides combined)	0.24% by mass, max.	0.25% by mass, max.

Witchakorn and Vitidsant (2003)[15]

The results of the dependent variables (Kinematic Viscosity, Density and Acid) of the experimental runs from the Table 1 and 2 will be compared with the standard in Table 3 for conformity to show that palm oil cracking exhibit renewable energy fuel properties. Equations (4) to (5) below represents mathematical models relating the production of oleochemicals with the independent process variables obtained from the statistical tool implemented on Design Expert. The design of the experimental matrix of both the experimental and the predicted values, calculated by Equations (4) to (5), are presented in the ANOVA tables below. The response was expressed as % yield; calculated as $\{Yo/V_{PF}\}$ x 100 where Y_o is the oleochemicals volume obtained after the cracking process and V_{PF} is the palm oil feed volume.

Mathematical relationship between the yield and the predictor variables for both thermal and catalytic cracking process is as presented in the equation below:

$$Y_{(\text{Thermal Cracking})} = 87.00 + 0.55X_1 + 0.91X_2 - 0.25X_1X_2 + 2.81X_1^2 - 0.31X_2^2 \quad (4)$$

$$Y_{(\text{Catalytic Cracking})} = 89.78 + 0.35X_1 + 0.1X_2 - 0.35X_3 + 0.40X_1X_2 + 1.25X_1X_3 + 0.90X_2X_3 + 2.61X_1^2 + 1.36X_2^2 - 0.11X_3^2 \quad (5)$$

Here, Y is the response variable (percentage of oleochemicals produced) and X_1-X_3 are the coded values of the independent variables. The above equations represent the quantitative effect of the factors (X_1, X_2, and X_3) upon the response (Y). Coefficients with one factor represent the effect of that particular factor while the coefficients with more than one factor represent the interaction between those factors. Positive sign in front of the terms indicates synergistic effect while negative sign indicates antagonistic effect of the factor. From the sequential test, it can be seen that the model F-values (13.57 and 15.84) of the quadratic models is large compared to the values for the other models for all the equations respectively. And from the statistics test, the regression coefficients (R^2 = 0.9065 and 0.9661) are high, and the adjusted R^2 (0.8397 and 0.9051) are in close agreement with the predicted R^2 (0.8044 and 0.9064) values respectively. These tests are shown in Tables 4 and 5.

TABLE IV. SIGNIFICANCE OF REGRESSION COEFFICIENTS ON THE THERMAL CRACKING PROCESS FOR OLEOCHEMICAL PRODUCTION USING THE STATISTICAL TOOL IMPLEMENTED ON DESIGN-EXPERT. ANOVA OF RESPONSE SURFACE QUADRATIC MODEL FOR THE THERMAL CRACKING

Source	Sum of Squares	df	Mean square	F Value	P-value Prob > F
Model	64.29	51	12.86	13.57	0.0017 significant
A-TEMP	2.44	1	2.44	2.5	0.0159
B-TIME	6.56	1	6.56	6.92	0.0339
AB	0.25	1	0.25	0.26	0.6233
A^2	55.03	1	55.03	58.08	0.0001
B^2	0.68	1	0.68	0.72	0.4251
Residual	6.63	7	0.95		
Lack of Fit	0.63	3	0.21	0.14	0.9306 not significant
Pure Error	6.00	4	1.50		
Cor Total	70.92	12			

Std. Dev. = 0.97; Mean = 85.08; C.V.% = 1.14; PRESS = 13.87; R^2 = 0.9065; Adj. R^2 = 0.8397; Pred. R^2 = 0.8044; Adeq. Precision = 10.6777

TABLE V. SIGNIFICANCE OF REGRESSION COEFFICIENTS ON THE CATALYTIC CRACKING PROCESS FOR OLEOCHEMICAL PRODUCTION USING STATISTICAL TOOLS IMPLEMENTED ON DESIGN-EXPERT. ANOVA OF RESPONSE SURFACE QUADRATIC MODEL FOR CATALYTIC CRACKING

Source	Sum of Squares	df	Mean square	F Value	P-value Prob > F
Model	80.77	9	8.97	15.84	0.0036 significant
A-TEMP	0.50	1	0.50	0.88	0.0307
B-TIME	0.000	1	0.000	0.000	0.0490
C-CATALYST	0.50	1	0.50	0.88	0.0307
AB	0.31	1	0.31	0.55	0.0419
AC	3.12	1	3.12	5.51	0.0157
BC	1.61	1	1.61	2.84	0.0153
A^2	52.60	1	52.60	92.83	0.0002
B^2	14.29	1	14.29	25.22	0.0040
Residual	2.83	5	0.57		
Lack of Fit	0.033	1	0.033	0.048	0.8379 not significant
Pure Error	2.80	4	0.70		
Cor Total	83.60	14			

Std. Dev. = 0.97; Mean = 85.08; C.V.% = 1.14; PRESS = 13.87; R^2 = 0.9065; Adj. R^2 = 0.8397; Pred. R^2 = 0.8044; Adeq. Precision = 10.6777

The ANOVA results for the models terms are given in Tables 4 and 5. Analysis of variance (ANOVA) was applied for estimating the significance of the model at 5% significance level and shown in tables above. A model is considered significant if the p-value (significance probability value) is less than 0.05 and not more than 0.1. From the p-values presented in Tables 4 and 5, it can be stated that all the linear terms X_1 and X_2 and interaction terms X_1^2 for oleochemicals obtained from thermal cracking, X_1, X_2, X_3 and interaction terms X_1X_2, X_1X_3, X_2X_3, X_1^2 and X_2^2 for oleochemicals obtained from catalytic cracking are significant model terms. Based on this, the insignificant terms of the models may be removed.

In terms of the actual factor values:

$$Y_{(\text{Thermal Cracking})} = -93.79534 + 0.45177 * \text{TEMP} - 0.032797 * \text{TIME} + 4.16667\text{E-}005 * \text{TEMP} * \text{TIME} - 2.81250\text{E-}004 * \text{TEMP}^2 - 8.68056\text{E-}005 * \text{TIME}^2 \quad (6)$$

$$Y_{(\text{Catalytic Cracking})} = +86.46490 + 0.0393203 * \text{TEMP} + 0.034632 * \text{TIME} - 0.17241 * \text{CATALYST} + 4.40496\text{E-}005 * \text{TEMP} * \text{TIME} + 4.16667\text{E-}004 * \text{TEMP} * \text{CATALYST} + 7.47039\text{E-}004 * \text{TIME} * \text{CATALYST} - 1.16049\text{E-}004 * \text{TEMP} - 3.78086\text{E-}004 * \text{TIME2} - 2.77778\text{E-}004 * \text{CATALYST2} \quad (7)$$

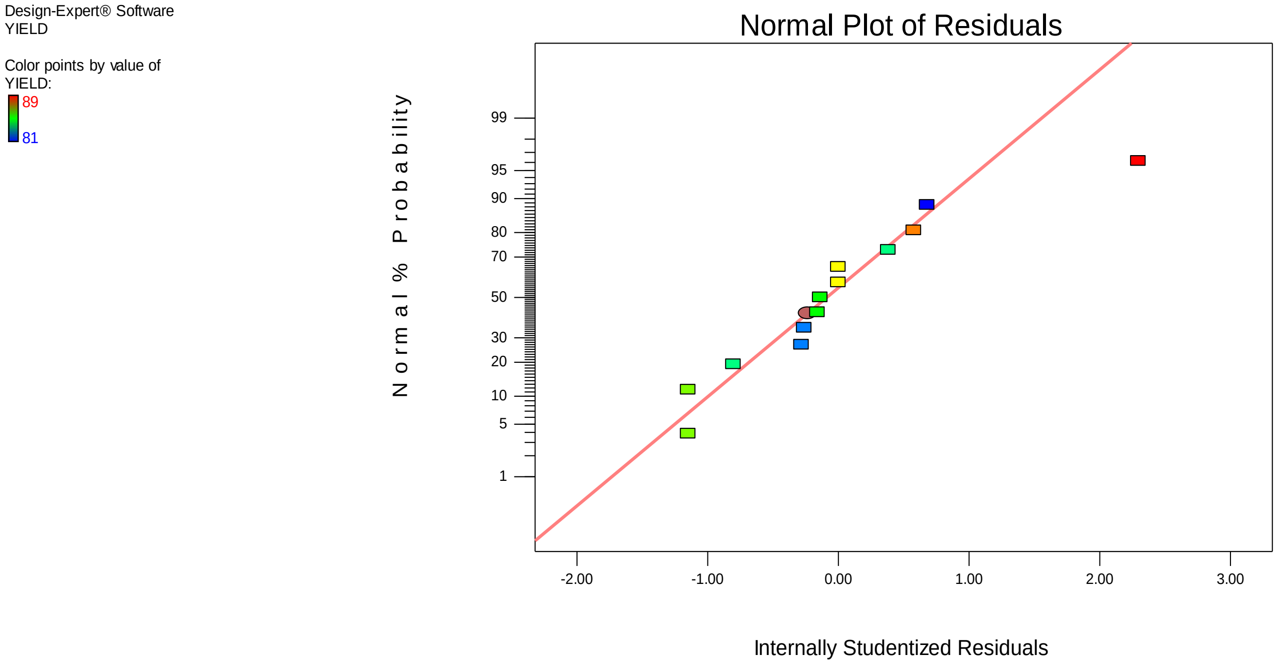

Figure 1. Plot of normal probability versus residuals for oleochemicals from thermal cracking

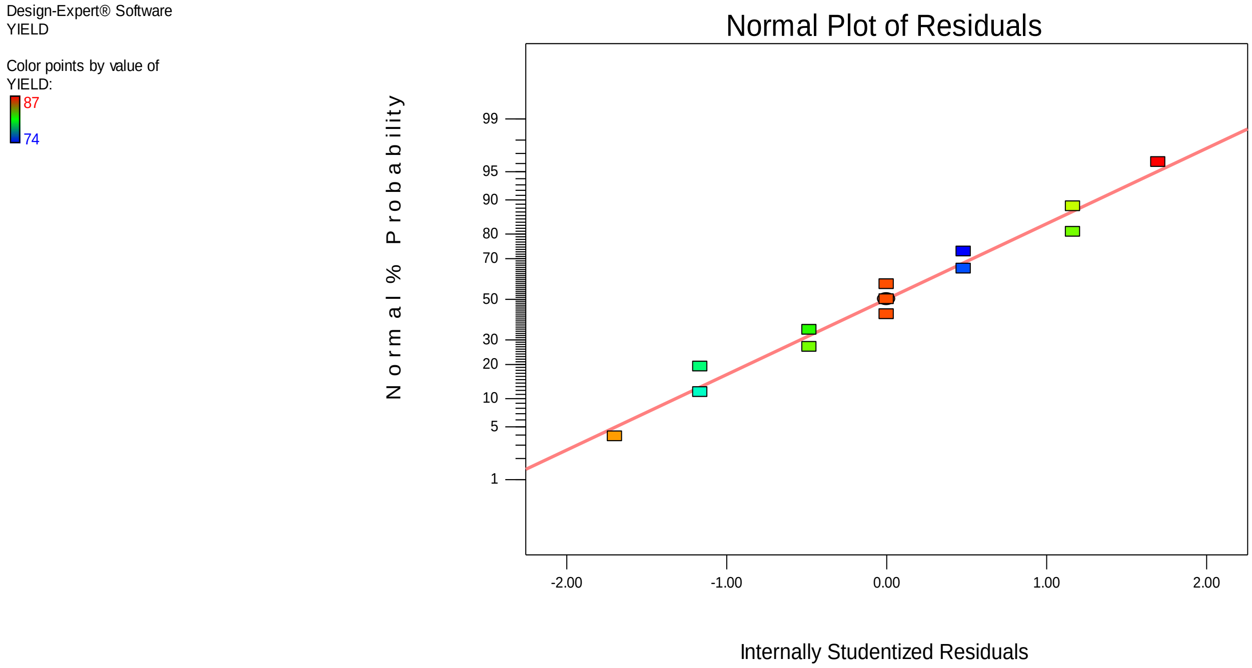

Figure 2. Plot of normal probability versus residuals for oleochemicals from catalytic cracking

From the plots above as shown in Figure 1 and 2, it is seen that the data points on the plot were reasonably distributed near to the straight line, also they are well correlated and are close to unity showing good results. However Figure 2 for the catalytic cracking gives a better correlation to Figure 1 for the thermal cracking process.

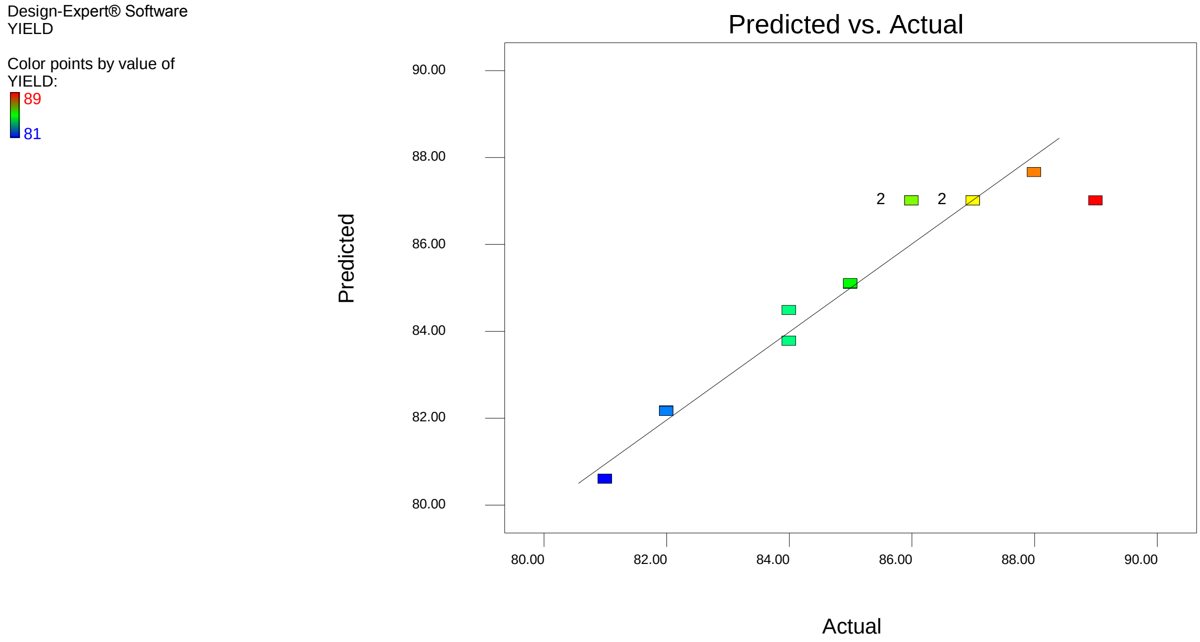

Figure 3. Plot of predicted values versus the actual experimental values for oleochemicals obtained from thermal cracking

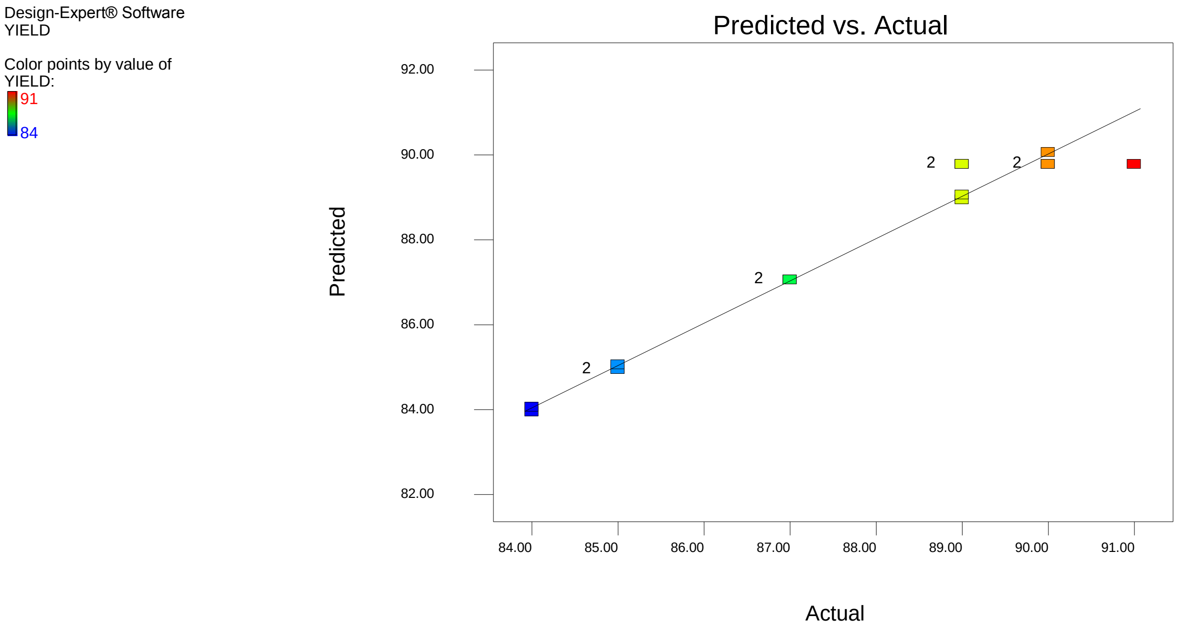

Figure 4. Plot of predicted values versus the actual experimental values for oleochemicals obtained from catalytic cracking

The experimental data in Tables above were also analyzed to check the correlation between the experimental and predicted plot, as shown in Figures 3 and 4. It can be seen from the Figures that the data points on the plot were reasonably distributed near to the straight line, indicating a good relationship between the experimental values from the laboratory and predicted values of the response by the statistical tool software. The result also suggests that the selected quadratic model was adequate in predicting the response variables for the experimental data.

B. *Three Dimensional Surface Plots for Thermal and Catalytic Cracking of Palm oil*

The 3D response surface plots were generated to estimate the effect of the combinations of the independent variables on the cracking process. One 3D plot was generated for thermal cracking while three 3D plots were generated for the catalytic cracking aspect of the work. The plots are shown in Figures 5 to 8. Figure 5 shows the dependency of percentage yield of oleochemicals from thermal cracking on temperature and time. As can be seen from the figure, % yield of oleochemicals produced increased as temperature gets to the mid point after which further increase causes a decrease in the % yield. The same trend was observed for the time variable but with a slight increase in the mid point of the plot. For the catalytic cracking, same phenomenon explained above also happens in the temperature versus time effect on the % yield of the oleochemicals produced. While for temperature relationship with catalyst on % yield, there is a sharp decrease in the % yield of oleochemicals after the mid point. It also shows that increase in catalyst weight as temperature increase reduces the % yield of oleochemicals produced.

For time relationship with catalyst over % yield, the optimum value was observed at the midpoint level of the plot. Overall, the catalytic cracking conditions with optimum point of 250^{o}C, Time of 90 minutes and Catalyst weight of 30 grams are preferable to the best condition from the thermal cracking because of the %yield, lower temperature conditions for the reactor and dependent variables (Acid value, Kinematic viscosity and density) conforming with the ASTM standard for production of oleochemicals which is analogous to biodiesel production.

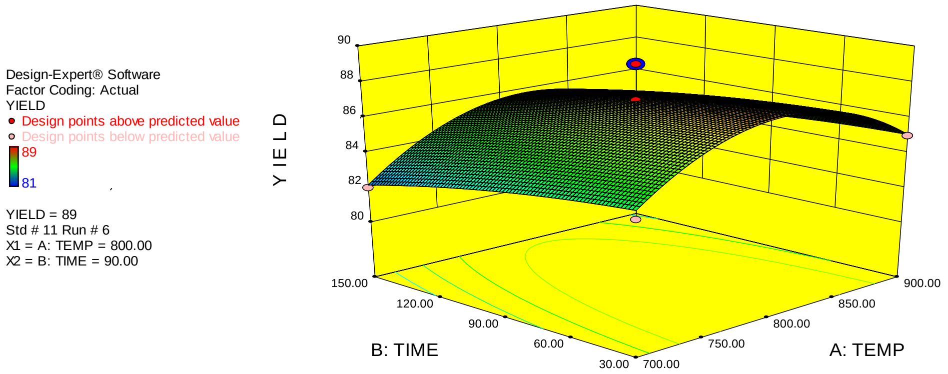

Figure 5. 3D Plot from thermal cracking showing the effect of time and temperature on the percentage yield of oleochemicals produced

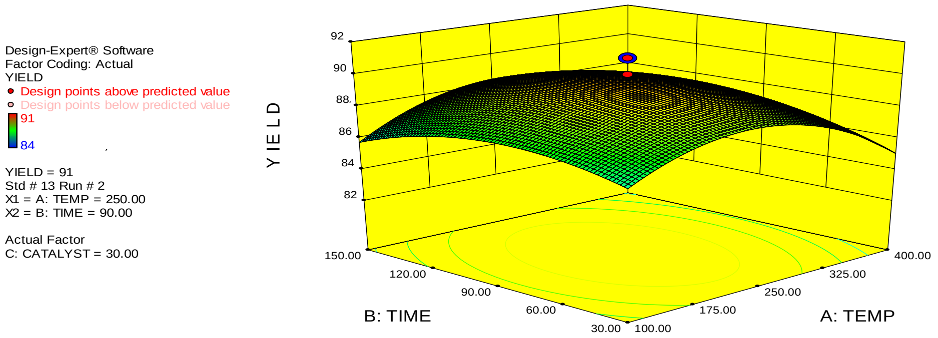

Figure 6. 3D Plot from catalytic cracking showing the effect of time and temperature on the percentage yield of oleochemicals produced

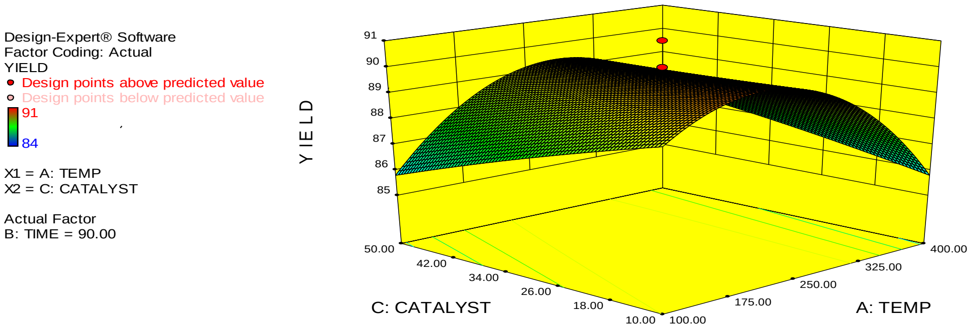

Figure 7. 3D Plot from catalytic cracking showing the effect of catalyst and temperature on the percentage yield of oleochemicals produced

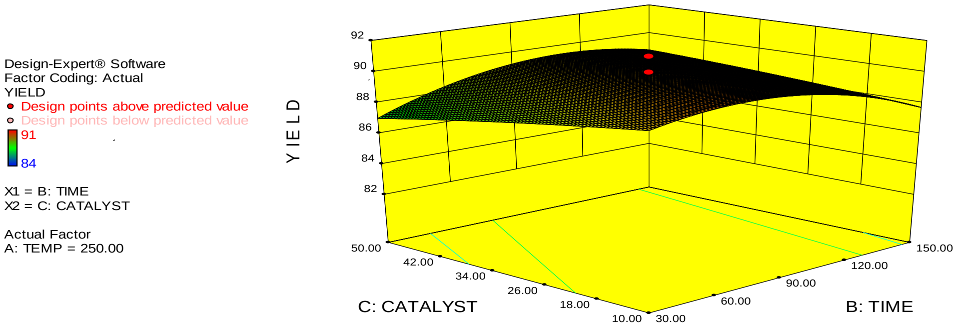

Figure 8. 3D Plot from catalytic cracking showing the effect of catalyst and time on the percentage yield of oleochemicals produced

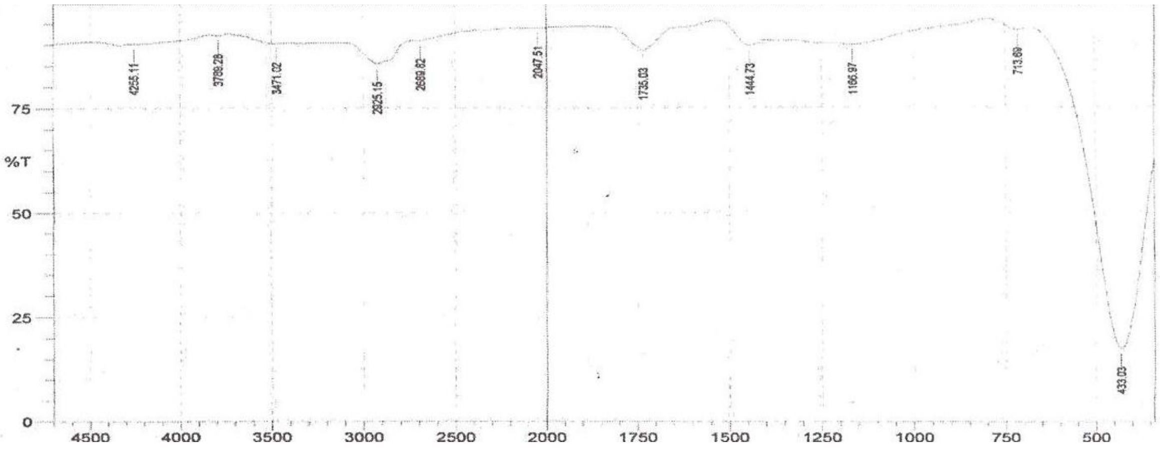

Figure 9. FTIR result of catalytic cracked palm oil sample (Temp: 250°C, Time: 90mins, Catalyst weight: 30 grams)

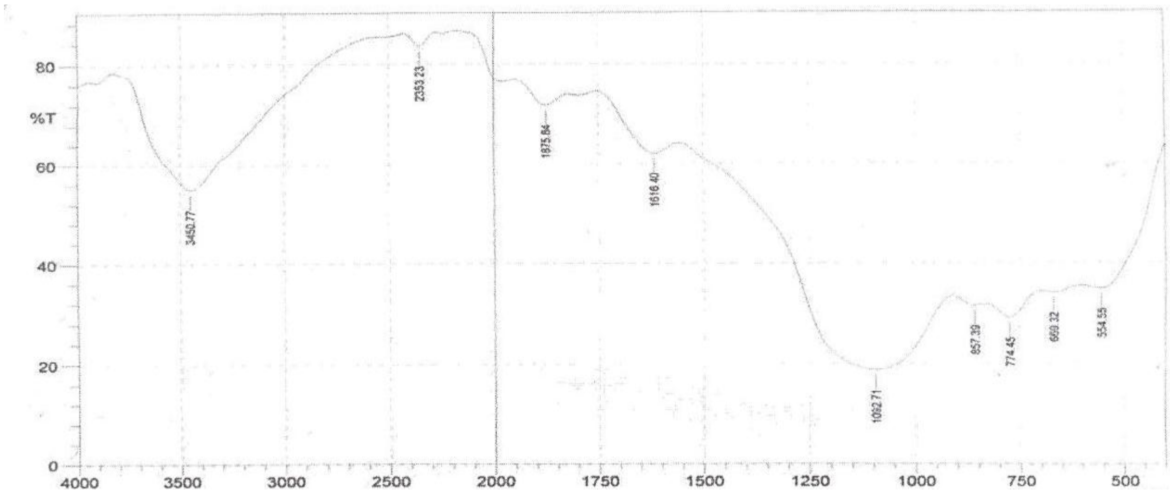

Figure 10. FTIR result of thermal cracked palm oil sample (Temp: 800°C, Time: 90mins)

TABLE VI. FOURIER TRANSFORM INFRARED SPECTRUM THERMAL CRACKED OIL

Wave number (cm^{-1})	Bond Source
612. 42	C – CL bend In alkyl Halides
752.26	C- 0 stretch in alcohols
1195.91	C – O Stretch in alcohol
1263.42	C-O Stretch in carboxylic acid
1418.69	C-H in plane bend in alkenes, aromatic phosphate
1584.57	N – H bend in amines, N-O in nitro compounds
1873.91	Aromatic Combination Bands
2261.61	C=N stretch Aliphatic cyanide/nitrile
3067.88	0 – H stretch in carboxylic acids
3178.79	O – H stretch in carboxylic acids
3351.43	N-H stretch in Aliphatic secondary amines
3394.83	O– H, Normal polymeric O-H stretch
3409.3	N – H stretch(1 per N-H bond) in amines
3547.21	O – H, H – bonded OH stretch
3655.23	O – H stretch in phenols and alcohols
3832.68	O – H stretch in phenols and alcohols
3901.16	O - H stretch in phenols and alcohols

TABLE VII. FOURIER TRANSFORM INFRARED SPECTRUM FOR CATALYTIC CRACKED OIL

Wave number (cm^{-1})	Bond Source
767.69	C-H bend (mono) in aromatics, methyl
927.79	Cyclohexane ring vibrations
1257.63	C – C Stretch in ketone, C-C(O)-C in ester, alcohol
1320.32	C=C Conjugation stretch in alkenes
1431.23	Methyl C-H asymmetric bend
1585.58	C = C-C, Aromatic ring stretch
1617.37	C- C stretch in alkynes
1774.7	C– H stretch in alkanes, ester
1873.91	Aromatic Combination Bands
2085.12	Transition metal carbonyl
2566.37	O-H stretch in carboxylic acids, alcohol, phenol
2677.29	O-H stretch in carboxylic acids, alcohol
3293.56	O– H, Normal polymeric OH stretch
3472.95	O – H, Dimeric OH stretch
3648.48	O – H stretch in phenols and alcohols
3842.33	O – H stretch in phenols and alcohols
3959.03	O – H, stretch in phenols and alcohols

In Fig. 5, maximum yield of oleochemicals was obtained as a result of the increase in temperature with a corresponding increase in time. In Fig. 6 the maximum yield of oleochemicals was obtained as a result of the increase in temperature with a corresponding increase in time but a better result is obtained for the catalytic cracking process to that of the thermal cracking process as seen in the nature of the curves. In Fig. 7, the maximum yield of oleochemicals will be obtained by an increase in temperature and a decrease in catalyst weight as shown by the curve. In Fig. 8, the maximum yield of oleochemicals will be obtained by an increase in temperature and a slight decrease in catalyst weight per each temperature gradient as shown by the curve.

IV. CONCLUSION

Oleochemicals with an optimum of 85-90% yield relative to the feedstock amount were obtained by cracking of vegetable palm oil in a batch reactor at temperatures of 100^{o}C - 400°C and 700 -900^{o}C for catalytic cracking and thermal cracking process respectively applied for the period of 30 to 150 minutes in the presence of activated clay for catalytic cracking of the palm oil sample. Response surface methodology design of experiment was used to achieve this means. The evaluation of products involved the effects of process parameters (Temperature, Time and catalyst weight) on acid value, density and viscosity. Viscosity, acid value and density of the liquid condensates falls within the accepted limit of the Biodiesel standard, and this shows that triglyceride molecules in the palm oil were broken down to light molecules and also showing that this is a good process used in obtaining oleo chemicals (fatty acid, fatty acid methyl esters and fatty alcohols) as shown in the FTIR results. It is also seen that the catalytic cracking values gave a higher yield to that of thermal cracking and the dependent variables were better suiting to that of thermal aspect of the cracking, therefore we conclude that catalytic cracking for this work is better off than the thermal cracking of the palm oil.

V. REFERENCES

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