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OPTIMAL BLEACHING CONDITION FOR PALM OIL

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ABSTRACT

This research was aimed at developing the optional palm oil bleaching process conditions using Enugu Clay as a local adsorbent. The conditions evaluated were temperature, time and the adsorbent dosage. The central composite design (CCD), a type of response surface methodology (RSM) was used. The research showed that the optimal bleaching process condition are clay dosage of

INTRODUCTION

Vegetable oil is a triglyceride extracted from a plant, such oil have been part of human culture for mellenia (Parwez, 2006). The term vegetable oil can narrowly be defined as substance that are liquid at room temperature (Robin ,1999). Vegetable oils are composed of triglycerides, as contrasted with wax which lack glycerin in their structures (Trans fat task force, 2006).

Many vegetable oils are consumed directly or indirectly as ingredient in food, a role that they share with some animal fats including butfers and ghee. Vegetable oils are also used as an ingredient or component in many manufactured products. Many vegetable oils are used to make soap, skin care products, condlet etc.

Palm oil is a vegetable oil rich in minor components such as carotenes (X-Carotenes and B-carotenes), tocopherols (X, B, Y and R tocopherols). The X-carotenes is important as processor of vitamin A and plays an important role in the prevention of cancer, cataracts and degenerative diseases such as heart disease (Choo, 2000).

Crude palm oil is the oil obtained from the mesocap of palm oil fruit, the crude palm oil produced is further processed to yield either red oil or bleached cooking oil.

3.6g at the temperature of 90°C and the time of 40 minutes with desirability of 0.93. The optimal conditions were validated by repeating the bleaching process at the predicated optimum conditions. Residual plots were used to validate the model equation developed. It is recommended that Enugu clay should be used as a local adsorbent in bleaching palm oil at the operating conditions above.

Palm oil and palm kernel oil have a wide range of application. About 80% are used for food application while the rest is feed. Stock for a number of non-food application (Salmiah, 2000).

Among the food uses, refined bleached and deodorized (RBD) oil are used mainly as cooking and frying oil. RDM palm oil, which is the unfracturated oil are used for producing margarise, vanaspat; (vegetable ghe) frying fat and ice cream (Salmiah, 2000).

Itiguchi (1983), stated that crude vegetable oil commonly consist of desirable triglycerides, unsaponifiable matter together with small amount of impurities. Most of these impurities contribute undesirable effect to the oil. For instance, colour, flavour, ordour, instability and forming.

These impurities should be removed in order to produce good quality refined oil with minimal possible oil loss or damage to the palm oil and desirable materials preserved in the oil such as carotenes and tecepherols.

Some of these chemical groups need to be removed partially or completely through the refining process in order to produce good edible oil that have better stability.

During bleaching process in palm oil refining, degummed oil is treated with bleaching clay and heated up to a temperatures of about 100°C before endering the vaccum bleacher. The dosage of acid activated clay used is typing within the range of 0.5-2.0% by weight of oil and contact time with continuous agitation for about 30 minutes (Djlkstra,2004).

At this stage, traces of metal components such as iron and copper pigments, phosphatides and oxidation products are removed during the stage. The bleached oil is then filtered (Patterson,2009)

There are several factors that affect the quality of bleached palm oil. Some of these factors include: the quality of the crude palm oil, bleaching time, operating temperature, operating pressure and bleaching earth dosage (Zschau 2000).
Optimization of the bleaching process is considerably important in achieving high quality refined oil. Naturally, bleaching clays are found in special strats and naturally active, thus used for bleaching. According to Sambanthamurthi (2000), natural clay are capable to; (i) decrease the chlorophyll and colour bodies (ii) remove soaps and immunize free fatty acid.

MATERIALS AND METHODS

The clay was obtained from Enugu, Enugu State south Eastern Nigeria at a dept of about 0.6m. The collected sample was ground and dispersed in excess water in a pretreatment plastic container and stirred vigorously to ensure proper dissolution. The dissolved clay was then filtered through a 0 .435mm mesh sieve to get rid of unwanted particles and plant materials. The sample was then sun dried and oven dried at 105^{o}C for 3 hours.
The dried sample was treated with 1.5m tetraoxosulphate (vi) acid at acid to clay ratio of 2:1. The activation was carried out in a round bottomed flask. The slurry was stirred continuously for 3 hours.
When activation was completed, the slurry was filtered and washed several times with distilled water until neutral PH was obtained. The sample was dried at 105^oC to reduce moisture content. The dried sample was ground and sieved using 0.19mm mesh sieve and stored in an air tight container.

BLEACHING

The bleaching was done using magnetically stirred hot plate, 100g of the sample was firstly heated on a hit plate to the required temperature while a known quanity of the adsorbent (clay) at the required time interval. At the completion of the time, the hot oil was passed through the adsorbent before measuring the adsorbence at 450nm using uv 1601 uv-visible spectrophotometer schimadzu. The bleaching capacity of the clay was determined from the equation

$$BC(\%) = \frac{A_o - A}{A_o} \text{ x } 100 \quad \dots\dots\dots \quad \text{I}$$

Where A_o and A are the adorbance of the raw oil and the bleached oil respectively, at the maximum wave height of the raw oil. The conditions of the bleaching is based on the design matrise.

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Experimental design

Central Composite design (CCD), a type of response surface methodology (RSM) was used for the optimization of the bleaching conditions. The factors studied were temperature (°C), time (minutes) clay dosage (% of oil weight).

The CCD was used to study the individual and synergistic effects of the three factors towards the bleaching efficiency (%). CCD is made up of three components; the axial runs, factorial runs and the centre runs. This gives the twenty experiments required for the design.

The factors and levels for the CCD are shown in table 1, while the design matrix is shown in table 2.

The experimental runs were randomized to minimize the effects of unexpected variability in the observed response. The response was used to develop a model that corrected the response to the process variable using second degree polynomial equation.

$$.\gamma = \beta_0 + \sum \beta_I X_i + \sum \beta_{ii} X^2{}_{iii} + \sum \beta_{ij} X_i X_j + \varepsilon \ldots \ldots \ldots .. (1)$$

Where Y is the predicted response variable, β_0 is the constant coefficient, β_i is the ith linear coefficient of the input variable Xi, β_{ij} is the different interaction coefficients between the input variables Xi and Xji and ε is the error of the model.

RESULTS

Optimization of bleaching conditions on the bleaching of palm oil using RSM

Table 1: Factors and Levels for the RSM

Variables	Units	-α	-1	0	+1	+ α
Time	Minutes	10	20	30	40	50
Temperature	°C	30	50	70	90	110
Clay dosage	% oil weight	1.8	2.4	3.0	3.6	4.2

Table II: Design Matrix with the Responses

Std	Run	Time (Mins)	Temp (°C)	Clay Dosage (% Oil Weight)	Experimental Value	Predicted Value
14	1	30.00	70.00	4.20	83.45	84.53
7	2	20.00	90.00	3.60	81.88	80.53
5	3	30.00	50.00	3.60	74.56	73.86

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17	4	30.00	70.00	3.00	77.69	75.94
12	5	30.00	110.00	3.00	84.00	85.14
19	6	30.00	70.00	3.00	77.20	75.14
16	7	30.00	70.00	3.00	73.67	75.94
13	8	30.00	70.00	1.80	69.77	67.36
18	9	30.00	70.00	3.00	77.01	75.94
9	10	10.00	70.00	3.00	68.00	69.86
3	11	20.00	90.00	2.40	75.90	74.46
1	12	20.00	50.00	2.40	61.20	62.75
10	13	50.00	70.00	3.00	80.93	82.03
20	14	30.00	70.00	3.00	75.65	75.94
4	15	40.00	90.00	2.40	78.60	80.55
8	16	40.00	90.00	3.60	88.25	86.62
11	17	30.00	30.00	3.00	66.90	66.75
1	18	40.00	50.00	2.40	68.59	68.84
15	19	30.00	70.00	3.00	74.69	75.94
6	20	40.00	50.00	3.60	80.93	79.94

ANALYSIS OF VARIANCE (AVOVA)

This is a collection of statistical models used to analyze the differences between group means and their associated procedures. It shows if the factors or models in your experiment are significant.

AVOVA for Response Surface 2FI Model

Table III: Analysis of variance table (Partial sum of squares – Type III)

Source	Sum of squares	df	Mean Square	F value	p-value Prob>F
Model	*797.47*	6	*132.91*	*47.71*	*<0.0001*
A-Time	*148.17*	*1*	*148.17*	*53.19*	*<0.0001*
B-Temperature	*338.10*	*1*	*338.10*	*121.36*	*<0.0001*
C-Clay dosage	*294.89*	*1*	*294.89*	*105.85*	*<0.0001*
AB	*2.75*	*1*	*2.75*	*0.99*	*0.3386*
AC	*0.88*	*1*	*0.88*	*0.32*	
BC	*12.68*	*1*	*12.68*	*4.55*	*0.1526*

Residual	36.22	13	2.79		
Lack of Fit	23.63	8	2.95	1.17	0.4495
Pure Error	12.58	5	2.52		
Cor Total	833.68	19			

The model F-value of 47.71 implies the model significant. There is only a 0.01% chance that a "Model F-value" this large could occur due to noise.
Values of "Prob>F" less than 0.0500 indicate model terms are significant.
In this case A, B, B are significant model terms Values greater than 0.1000 indicate the model terms are not significant.

Experimental Design

Experimental design is the response obtained from the laboratory which is used to check the interactive significant effects of the process factors involved in an experiment.
In developing an optimal bleaching process conditions for vegetable oil refining, Response Surface Model (RSM) is used because we are required to model and optimize the process.

Model Equation

Final Equation in Terms of Coded Factors:

Bleaching efficiency = +75.94 + 3.04 x A + 4.60 x B + 4.29 x C – 0.59 x A x B + 0.33 x A x C – 1.26 x B x C

Final Equation in Terms of Actual Factors:

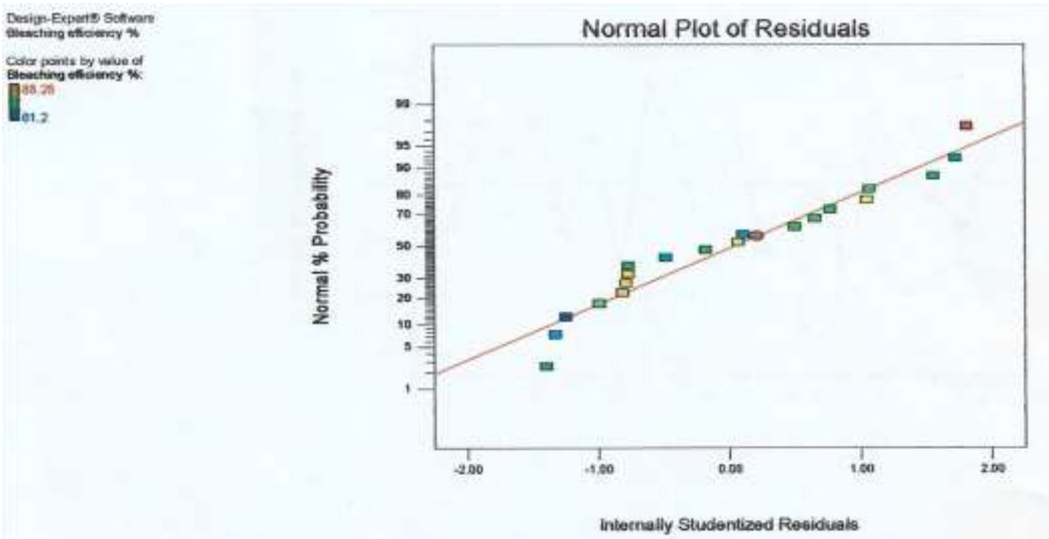
Bleaching efficiency = + 6.04444 + 0.34387 x Time + 0.63247 x Temperature + 12.84167 x Clay dosage – 2.93125E-003 x Time x Temperature + 0.055208 x Time x Clay dosage – 0.10490 x Temperature x Clay dosage.

VALIDATION OF MODEL

To diagnoses or validate the model equations obtained, residual plots were used.

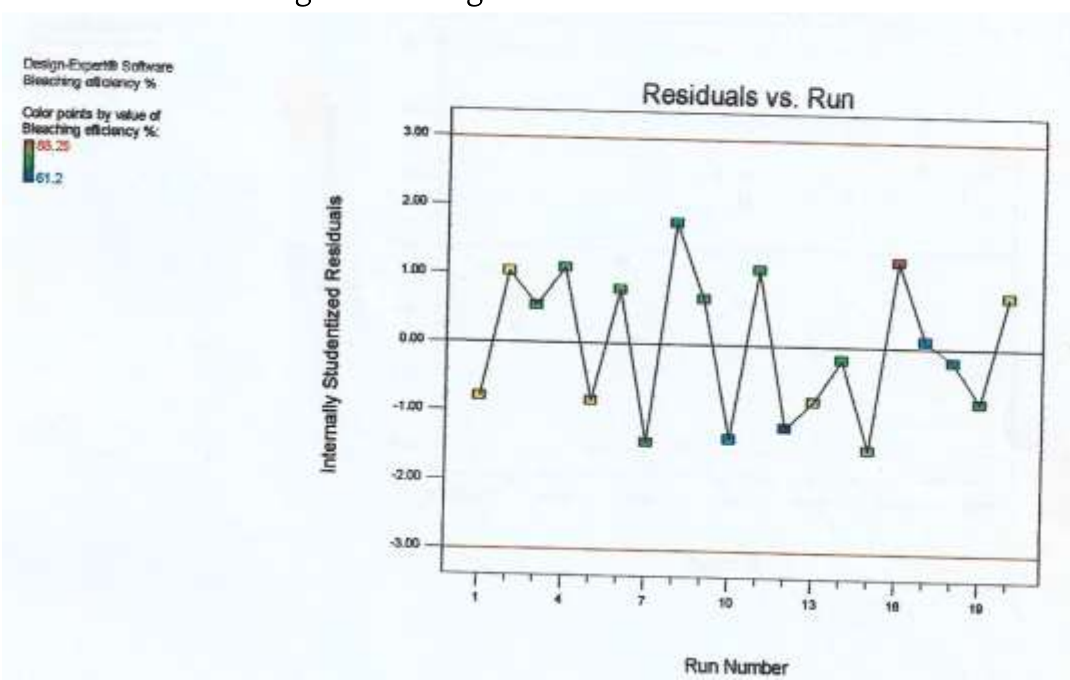
Normal Plot of Residuals

The normal probability plot indicates whether the residuals follow a normal distribution, in which case the points will follows a straight line. Expect some moderate scatter even with normal data.



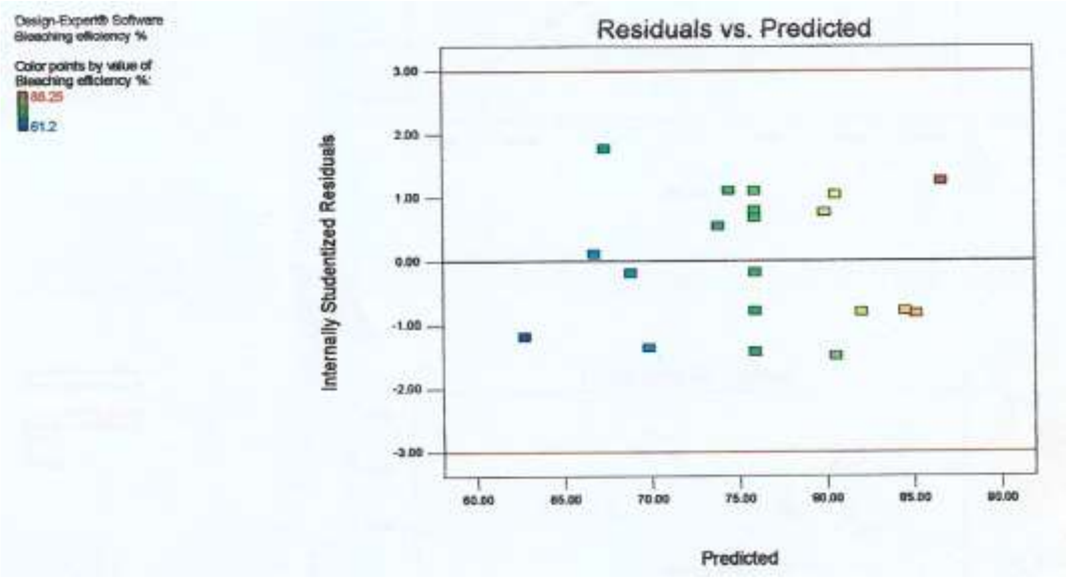
Residual vs Run

This is a plot of the residual versus the experimental run order. It allows you to check for lurking variable that may have influenced the response during the experiment. The plot should show a random scatter. Trends indicate a time-related variable lurking in the background.

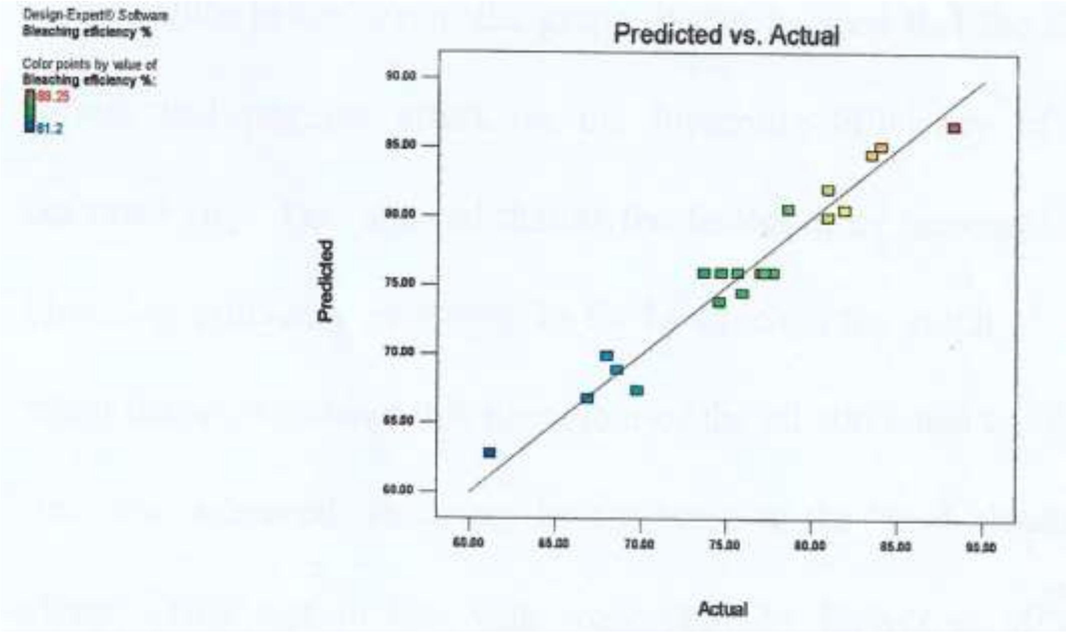


Residuals vs Predicted Plot

This is a plot of the residuals versus the ascending predicted response values. It tests the assumption of constant variance. The plot should be a random scatter (constant range of residuals) across the graph.



Predicted vs Actual



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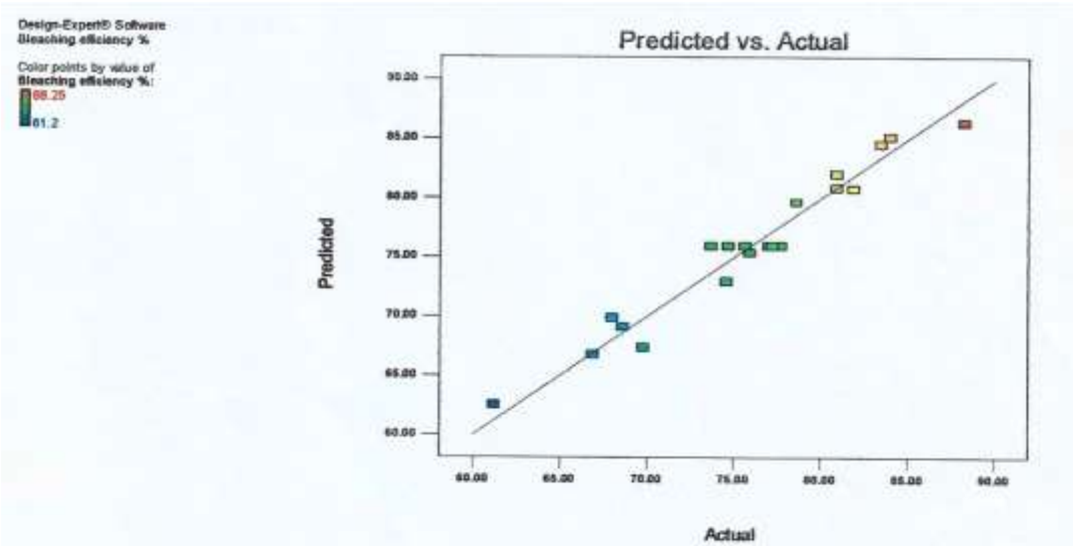
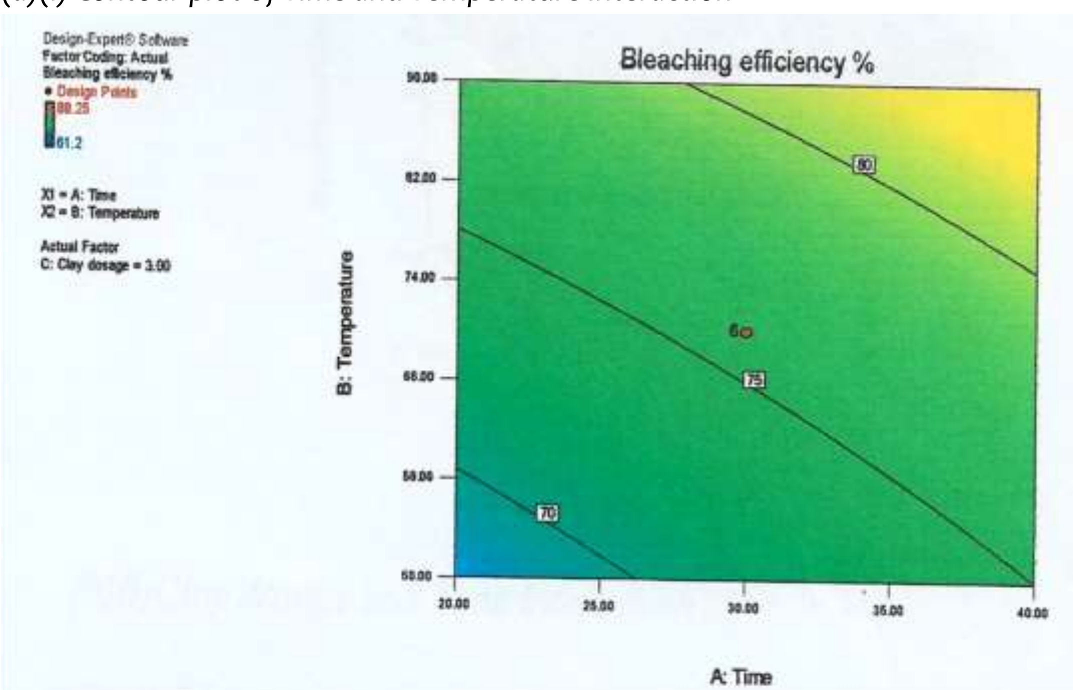


A graph of the actual response values versus the predicted response values. It helps you detect a value, or group of values, that are not easily predicted by the model. The data points should be split evenly by the 45 degree line.

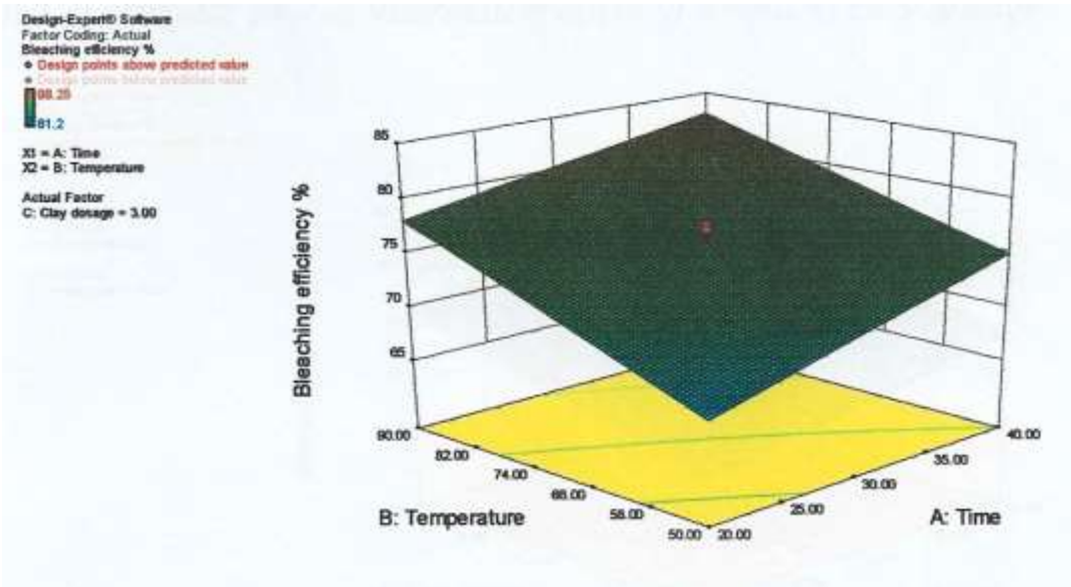
INTERACTION EFFECTS

Fig. 2

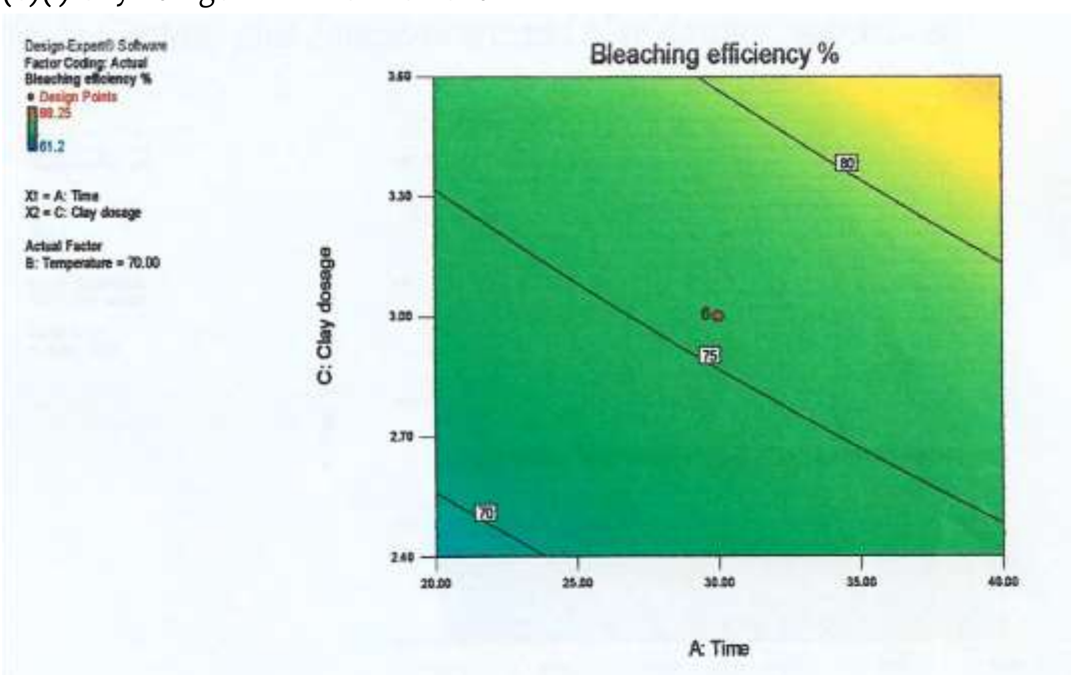
(a)(i) Contour plot of Time and Temperature interaction



(ii) 3D surface plot of interaction effect of time and temperature



(b)(i) Clay dosage and Time interaction



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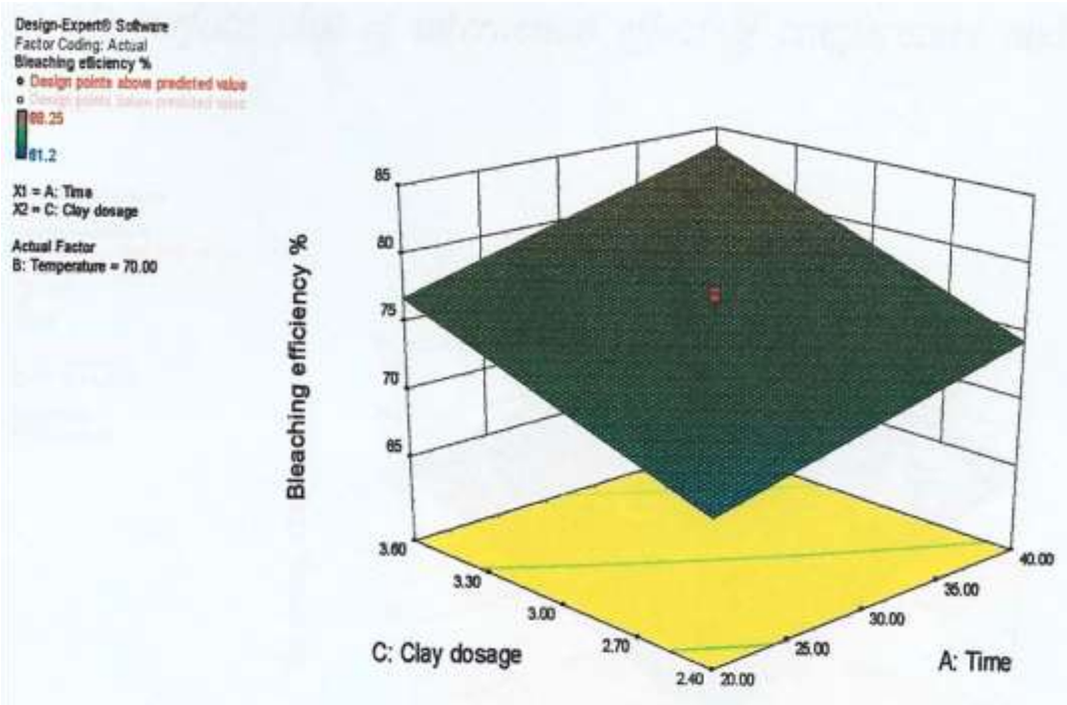
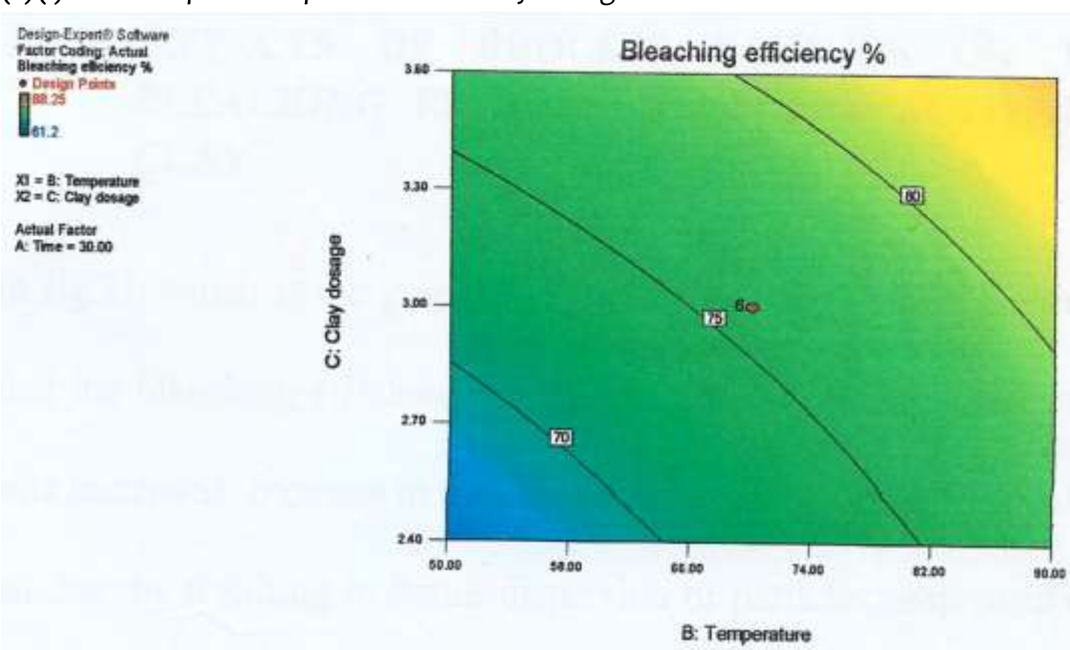
(ii) 3D surface plot of interaction effect of time and clay dosage



(c)(i) Contour plot Temperature and clay dosage interaction



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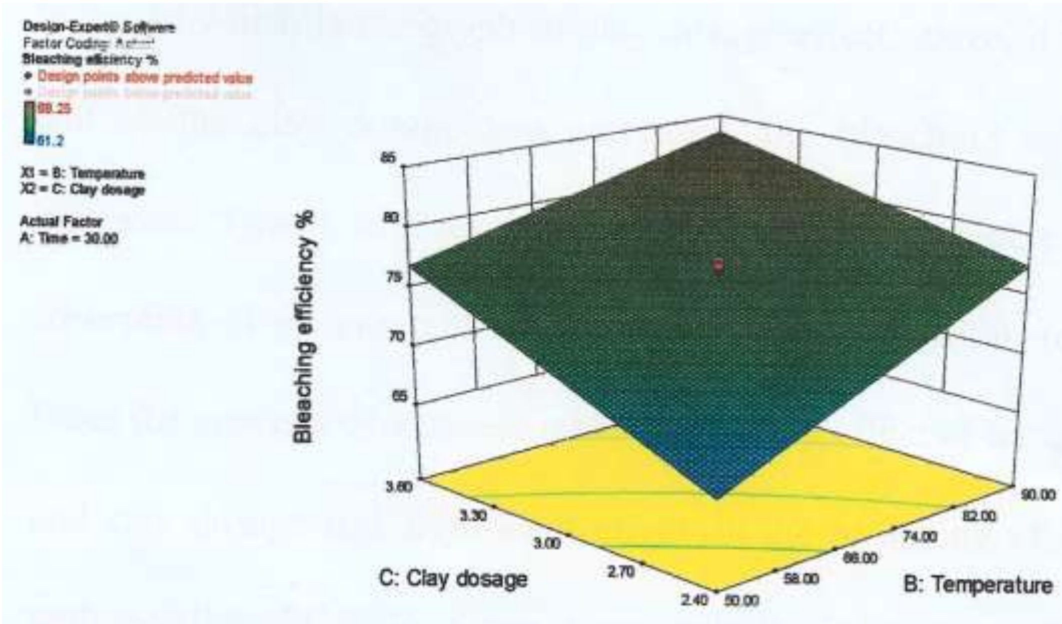
(ii) 3D surface plot of interaction effect of temperature and clay dosage



EFFECTS OF PROCESS FACTORS ON THE BLEACHING EFFICIENCY OF THE ACTIVATED CLAY

In fig 1b which is the graph of temperature effect above, it showed that the bleaching efficiency of the oil increased as the temperature was increased. Increase in temperature decreases the viscosity of the oil thereby resulting in better dispersion of particles, improved clay oil interaction and flow ability (Nwabanne J.T, Ekwu F.C; 2013), and it can equally be attributed to heat bleaching effect.

In fig 1c which is the graph of clay dosage effect above, it showed that as the clay dosage was increased, the bleaching efficiency increased. This is as a result of high surface area available for the adsorption of the carotene thereby leading to more colour removal. From the analysis of variance table, interaction effect of temperature and clay dosage had significant effect on the bleaching efficiency, with p-value of 0.0526. Since it was only the interaction effects on the temperature and clay dosage that was significant, its plot was analyzed.

From the interaction effect graph in fig 2ci above, it showed that as temperature was increased at both low and high value of clay dosage, the bleaching efficiency increased. The increase at the higher clay dosage was more than that at lower clay dosage due to large surface area availability.

The contour plot in fig 2ci showed that bleaching efficiency was increased as the temperature and clay dosage was increased.

The 3D surface plot in fig 2cii showed a flat surface confirming the linear nature of the model. The sloppy nature of the surface indicated that the bleaching efficiency was reduced as the temperature and the clay dosage decreased. The minimum bleaching efficiency was obtained at lower temperature and lower clay dosage while the maximum bleaching efficiency was achieved at higher temperature and higher clay dosage.

OPTIMIZATION

Numerical optimization was used to search the design space using the model created to find factor settings that met the desired goal of maximal bleaching efficiency. With 20 solutions found, the optimal conditions were selected based on the highest desirability. The optimum conditions are: time of 40mins, temperature of 90^{0}C, clay dosage of 3.6g with bleaching efficiency of 86.629% at desirability of 0.930. the optimum conditions were validated by repeating the bleaching at the predicted optimum conditions.

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