

EVALUATION OF OPTIMAL CONDITIONS FOR CRUDE PALM OIL BLEACHING ON LOCALLY PREPARED ACTIVATED CARBON USING RSM-GA AND A HYBRID ANN-GA

Babayemi, A. K.^{1,a*}, Onukwuli, O. D.^{2,b} and Emmanuel Emeka Eluno, E. E.^{3,c}

^{1,3}D epartment Of Chemical Engineering, Chukwuemeka Odumegwu Ojukwu University, Nigeria

²Department of Chemical Engineering, Nnamdi Azikiwe University, Awka, Nigeria

^aakinbabs40@yahoo.com, ^bonukwuliod@yahoo.com, ^cnuelsmart27@gmail.com

Abstract

The acceptability of palm oil as edible cooking oil, as well, as for industrial uses is limited to the associated impurities and the need to improve on its quality to meet the required standards for both human and industrial uses through bleaching, form the basis for this work. Optimal conditions for colour removal from crude palm oil on locally prepared activated carbon were investigated. Palm oil was obtained from local producers at Uli, Ihiala Local Government of Anambra State, Nigeria. The obtained palm oil was subjected to pretreatment and physico-chemical analysis before bleaching. The activated carbon used as bleaching material was locally prepared from animal bone through carbonization and chemical activation processes. The prepared activated carbon (ABAC) was characterized using Fourier Transform Infrared (FTIR), Scanning Electron Microscopy (SEM), Braummer-Emett-Teller (BET) and X-ray Diffraction (XRD). Bleaching of the prepared palm oil on ABAC was done at different process conditions. A bench scale experiment was conducted and the data so obtained were optimized using Response Surface Methodology and Hybrid Artificial Neuron Network- Genetic Algorithm. The characterization results of BET analysis show that ABAC has a surface area of 593.270m²/g, micro pore surface area 595.56 m²/g, micro pore volume 0.212cm³/g, Langmuir surface area 1.38e+04m²/g and adsorption energy 3.998KJ/mol. XRD analysis shows the presence of Gypsum, Brushite, Calcium Hydrogen Phosphate Hydroxide and Ardealite with Gypsum indicating its highest peak at 2θ angle 12° and X-ray count above 2500 which indicates its dominance in the ABAC. The ANN gave a regression coefficient (R²) value of 0.987, while that of RSM was 0.861. This shows that ANN can account for more than 98.7% of the variability in the system while RSM can only account for 86.1% for the system. The ANN model shows good fitting with the experimental data and gave better performance than RSM as seen from the results. Optimum conditions which guaranteed maximum 92.31% color reduction were selected after observing the results of the GA. The optimized conditions were obtained as follows; 25g adsorbent dosage, 46mins adsorption time and 104.32°C adsorbent temperature. It could be established that model equations were developed, optimal adsorption parameters were estimated for palm oil bleaching on a non-toxic, low cost, biodegradable activated carbon produced from waste animal bone.

Keywords: Evaluation; process parameters; bleaching; activated carbon; genetic algorithm; palm oil.

1.0 Introduction

Elaeis guineensis, the African oil palm, is a major source of palm oil for both human and industrial uses. It is largely cultivated in Africa. Nigeria produced approximately 2.3 million hectares in the year 2011. [1, 2]. Palm oil, a vegetable oil safe for consumption, is derived from the mesocarp of the fruit of the oil palms. It is composed of fatty acids esterified with glycerol. Its characteristic dark red colour may be due to the presence of high concentration of carotenes such as alpha-carotenes, beta-carotenes and lycopene. The acceptability of palm oil as an edible cooking oil, as well as, for industrial uses is limited owing to the associated impurities such as gums, waxes, free fatty acids, carotenoids, xanthophyll, xanthophyll esters, chlorophyll, tocopherols, oxidized fatty acids and fatty acid polymers and unpleasant odour [3, 4].

Also, immoderate consumption of palmitic acid which makes up 44% of palm oil results in high blood level which poses a risk of cardiovascular diseases [5-7]. Consequently, the need to improve the quality of palm oil to meet the required standards for both human and industrial uses prompt the search for the appropriate purification process and materials in this study. The bleaching of edible oils and fats is a part of the refining process of crude oils and fats, which removes contaminants that adversely impact the appearance and performance of these triglyceride based materials. Typically, edible oils and fats, ranging from soya beans and palm oils to edible lard and beef tallow are extracted together with impurities in various quantities. Many of these impurities have to be removed from the oil to achieve the high quality standards necessary for edible applications. During the bleaching process, adsorption occurs via many different mechanisms involving various physical and chemical interactions. Palm oil bleaching by adsorption is one of those mechanisms that require a suitable adsorbent. In this study, animal bone activated carbon was used as an adsorbent to

optimize color removal for crude palm oil. Review of relevant literature shows that adsorption time, adsorbent dosage and temperature are the significant parameters that influence the bleaching of palm oil [8]. The present study therefore considers the optimization of all these three parameters in the bleaching of palm oil to achieve an optimal percentage color reduction

Bleaching has been the most commonly adopted method among many researchers for the purification of crude palm oil using Fuller's Earth or local clays as adsorbents [9] but their application has been restricted for lack of thermal stability [10]. Clay materials are characterized by layered structures consisting of sheets of silicon oxide alternating with sheets of aluminum oxide. Units of two or three sheets constitute unit layers which can be affected at very high temperature. This calls for a pillaring process to improve stability and enhance chemical activity of the clay besides, the elemental, mineralogical and biological constituents of clays, some of which may be contaminants, raise a serious concern as regards the quality of the bleached palm oil using clays as adsorbents.

However, some researchers have also established the use of activated charcoals, nutshells, snail shells and bagasse as alternative to clays as adsorbents [11] but little or no effort has been made on the low cost, non-toxic, eco-friendly and bio-degradable animal bone for palm oil bleaching. Hence, the need to study the adsorptive potentials of animal bone based activated carbon for palm oil bleaching which forms the basis for this research.

2.0 Materials and Methods

2.1 Preparation of the Adsorbent

Cow bone samples were collected from a major abattoir in the city of Uli, thoroughly washed with hot water and dried. The dried samples were subjected to size reduction before carbonization in a muffle furnace at 600°C for 2hrs. The charred material, after cooling to room temperature, was further activated chemically with 2M H₂SO₄ in order to improve its active sites for adsorption. The obtained activated carbon was then sieved into the required particle size of 0.2mm ready for use.

2.2 Crude Palm oil Refining

The crude palm oil was degummed by its mixture with hot water through a separating funnel. The obtained degummed oil was further subjected to neutralization process using NaOH solution for the purpose of removing free fatty acid (FFA) present in the oil.

2.3 Experimental Procedure

5g of activated carbon was added to 20ml of refined palm oil at 40°C and centrifuged at 200rpm for 20mins. The result was tested for absorbance in a UV-spectrophotometer set at 446nm using iso-octane as blank. The same procedure was repeated for the remaining dosages of the adsorbent at the temperatures of 60°C, 80°C, 100°C and 120°C respectively.

2.4 Statistical Modeling

A full- factorial design (FFD) was used for the design of experiment characterizing the full effects of the three factors at five distinct settings enhanced by experimentation. In order to study effects of these variables on the responses, statistical analysis and optimization will be required for fitting suitable predictive model from regression analysis to the resulting data [12-13]. The model may be represented as:

$$Y = \beta_0 + \sum_{j=1}^k \beta_j X_j + \sum_{j=1}^k \beta_{jj} X_j^2 + \sum_{i < j} \sum_{j=2}^k \beta_{ij} X_i X_j + \varepsilon \quad (1)$$

Where; Y is the response (% color reduction) of the palm oil bleaching process; β_0 represents the model intercept, $\beta_j, \beta_{jj}, \beta_{ij}$ are the linear, quadratic and the interaction coefficients respectively, $X_j, X_j^2, X_i X_j$ characterize the main linear, quadratic and the interaction effects between the variables respectively whereas ε is the experimental random. X_{ij} represents the input variables in the regression function, k=3 is the total no of variables. Table 1 presents the coded values of the independent parameters of the experimental design for palm oil bleaching. To facilitate construction of experimental designs with easy computation, coded variables X1, X2, X3 were used to represent the input variables, this also ensures accurate estimation of the model coefficients and enhanced interpretability of the coefficient estimates. The unknown coefficients of equation (1) were evaluated by applying the design matrix of Table 2, formulated by carefully transforming the actual values of the three control variables at various levels to their coded equivalents with '-1' and '+1' notations designating low and high level factor setting and ' $\pm\alpha$ ' and '0' axial and center points respectively.

Table 1: Experimental range and level of the input variables for palm oil bleaching.

Independent variable	Range and level				
	- α	-1	0	1	+ α
Adsorbent dosage (g)	5	10	15	20	25
Adsorption time (min)	20	30	40	50	60
Temperature ($^{\circ}$ C)	40	60	80	100	120

A global design matrix of Table 2 was formed from the data given in Table 1, Y is the response (percentage color reduction) across the various experimental runs. The experimental data were fitted to the second-order polynomial regression model using the statistical and machine learning toolbox of MATLAB 2015a of Maths Work Inc. to obtain the final equation for prediction of the bleaching process in terms of coded factors. The residuals were tested for normality using histogram plot and probability plot of residuals. Statistical analysis was performed in MATLAB for the: analysis of variance (ANOVA), regression analysis and response surface plots of the interaction effects of the factors to evaluate the effects of the process variables on the bleaching efficiency, the suitability of the model in describing the bleaching process and determine the optimum conditions for the bleaching process. The significance of the regression coefficients was measured by p-value.

Table 2: Full Factorial Design Matrix For Palm Oil Bleaching Process

X ₁ (g)	X ₂ (min)	X ₃ ($^{\circ}$ C)				
		- α	-1	0	+1	+ α
		Y (%)	Y (%)	Y (%)	Y (%)	Y (%)
- α	- α	48.44	50.69	53.40	56.77	55.04
	-1	51.52	55.18	56.86	59.75	58.73
	0	61.34	62.09	62.80	63.68	59.10
	+1	61.90	62.24	64.42	66.01	59.95
	+ α	60.93	62.06	63.60	64.87	59.06
-1	- α	50.41	52.71	54.70	57.97	56.86
	-1	55.55	56.48	58.82	62.28	62.83
	0	63.77	65.45	66.10	66.30	65.55
	+1	64.14	65.83	66.58	67.14	65.64
	+ α	63.51	63.88	65.98	66.17	63.88
0	- α	53.47	54.79	55.36	57.88	56.41
	-1	57.88	57.85	60.71	64.25	63.68
	0	58.78	60.91	62.11	69.95	67.14
	+1	62.35	62.65	65.83	72.85	70.04
	+ α	60.27	61.67	64.86	71.23	69.86
+1	- α	50.44	53.96	55.71	63.40	57.51
	-1	55.71	58.06	59.59	66.49	62.83
	0	61.74	62.83	62.95	67.41	66.11
	+1	62.65	65.27	65.83	68.04	66.59
	+ α	60.28	61.85	64.26	67.05	65.44
+ α	- α	54.81	57.89	59.24	65.35	63.86
	-1	60.27	65.36	67.73	72.22	70.02
	0	64.61	68.35	70.06	76.66	73.86
	+1	67.82	69.20	74.41	78.04	77.55
	+ α	66.94	67.32	73.21	76.08	75.04

2.5 ANN modeling

In fitting problems, a neural network maps between a data of numeric inputs and a set of numeric targets. In this work, the neural network Toolbox of MATLAB 2015a was used in training a neural network to model the percentage color removal

during the adsorption process for bleaching of palm oil. . The network was trained using Levenberg-Marquardt back propagation algorithm. The input data presented for the network training consisted of 125 samples of 3 elements corresponding to adsorbent dosage, adsorption time and temperature and the target data was 125 samples of 1 element corresponding to the percentage color reduction. The data sets were randomly divided into three sets of 70%, 15% and 15% for network training, validation and testing respectively. The training data set were presented to the network during training and the network was adjusted according to its error, the validation data set were used to measure network generalization and to halt training once the generalization stopped improving while the testing data set has no effect on the training and hence provides an independent measure of the network performance during and after training. The network was trained with 10 neurons in the hidden layer which gave the optimal prediction performance. Training automatically stopped when generalization stopped improving as indicated by an increase in the mean square error of the validation samples. The mean square error is the average squared difference between outputs and targets; lower values are better with zero value signifying no error. Regression R values measure the correlation between outputs and targets, an R value of 1 means a close relationship and 0 a random relationship [14].

2.6 Genetic Algorithm (GA) Optimization Technique.

The underlying idea of genetic algorithms applied to this problem is as follows: The algorithm started with an initial set of points in the data set, denoted $P(0)$, called the initial population, then the objective function at points in $P(0)$ were evaluated. A new set of points $P(1)$ was created based on the evaluation which involved certain operations on points in $P(0)$, called crossover and mutation [15]. The procedure was then repeated iteratively, generating populations $P(2), P(3), \dots$ until an appropriate stopping criterion was reached. The purpose of the crossover and mutation operations was to create a new population with an average objective function value that is higher than that of the previous population. In the present work, GA optimization was applied to determine the optimal conditions for percentage color removal using a code developed in MATLAB. The results from the ANN model were tested for process conditions that will guarantee an optimal color removal.

3.0 Results and Discussion

3.1 Characterization Results

Fig.1 shows the XRD pattern of ABAC with the number of counts (intensity) on the vertical axis and the corresponding 2-theta angle on the abscissa. The mixed-layered minerals or compounds present are Gypsum, Brushite, Calcium Hydrogen Phosphate Hydroxide and Ardealite with gypsum showing highest peak indicating its dominance in the ABAC. Gypsum has its highest peak at 2 θ angle about 12 $^{\circ}$ and X-ray count above 2500.

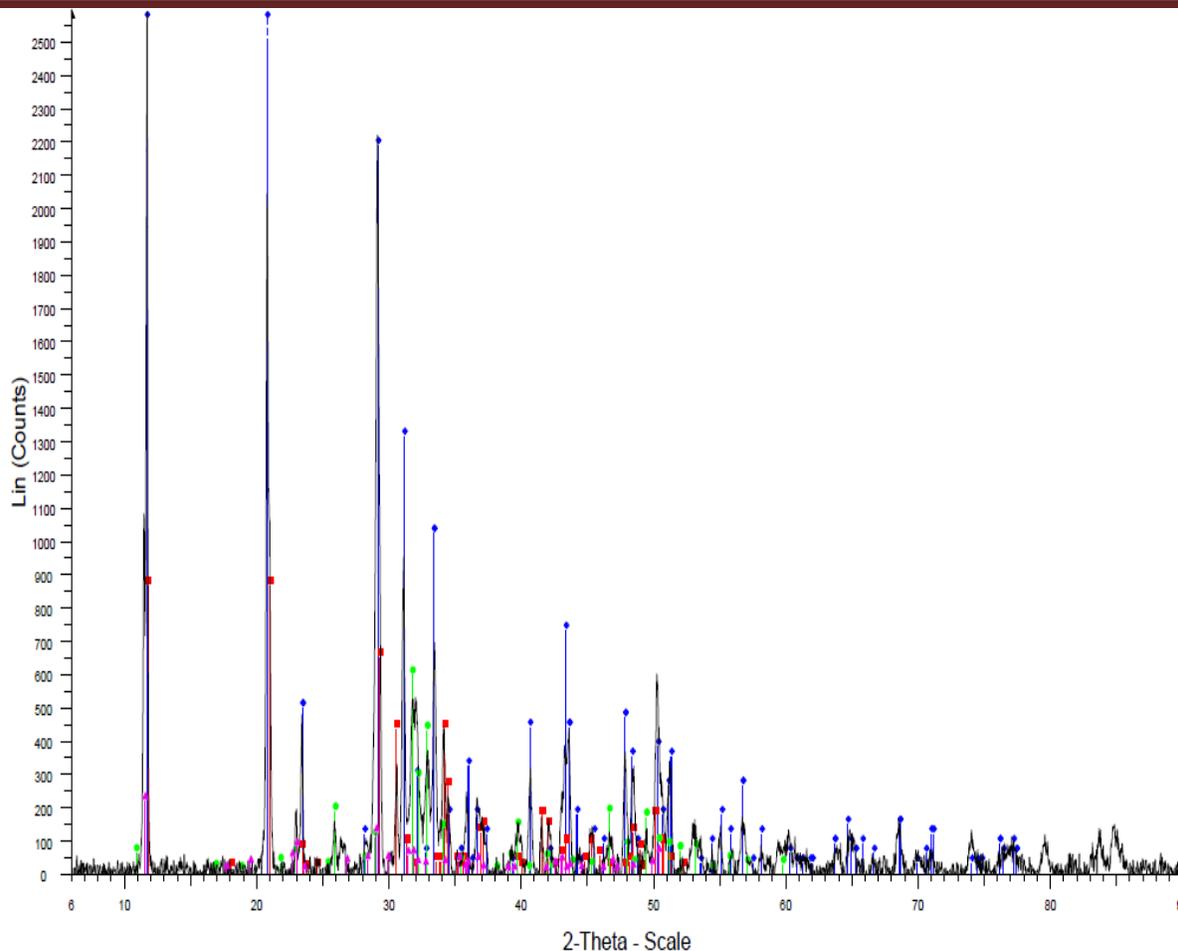


Fig. 1: XRD pattern on intensity versus 2-theta graph

File: bgnd_ANA.raw - Type: 2Th/Th locked - Start: 6.000 ° - End: 90.008 ° - Step: 0.034 ° - Step time: 98. s - Temp.: 25 °C (Room) - Time Started: 9 s - 2-Theta: 6.000 ° - Theta: 3.000 ° - Chi: 0.00 ° - Phi: 0.00 ° - X: 0.
Operations: Import

- 00-033-0311 (*) - Gypsum, syn - $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ - Y: 112.50 % - d x by: 1. - WL: 1.5406 - 0 - I/Ic PDF n.a. - I/Ic User n.a. - S-Q n.a. - F30= 51(0.0120,48)
- 00-009-0077 (*) - Brushite, syn - $\text{CaPO}_3(\text{OH}) \cdot 2\text{H}_2\text{O}$ - Y: 33.33 % - d x by: 1. - WL: 1.5406 - 0 - I/Ic PDF n.a. - I/Ic User n.a. - S-Q n.a. - F30= 68(0.0118,37)
- 00-048-0805 (*) - Calcium Hydrogen Phosphate Hydroxide - $\text{Ca}_8\text{HPO}_4(\text{PO}_4)_5\text{OH}$ - Y: 22.82 % - d x by: 1. - WL: 1.5406 - 0 - I/Ic PDF n.a. - I/Ic User n.a. - S-Q n.a. - F30= 37(0.0230,35)
- 00-041-0585 (I) - Ardealite - $\text{Ca}(\text{SO}_4)(\text{PO}_3\text{OH}) \cdot 4\text{H}_2\text{O}$ - Y: 8.33 % - d x by: 1. - WL: 1.5406 - 0 - I/Ic PDF n.a. - I/Ic User n.a. - S-Q n.a. - F30= 10(0.0410,72)

FTIR analysis which identifies the functional groups necessary for the adsorption process as displayed by various peaks is presented in Fig. 2.

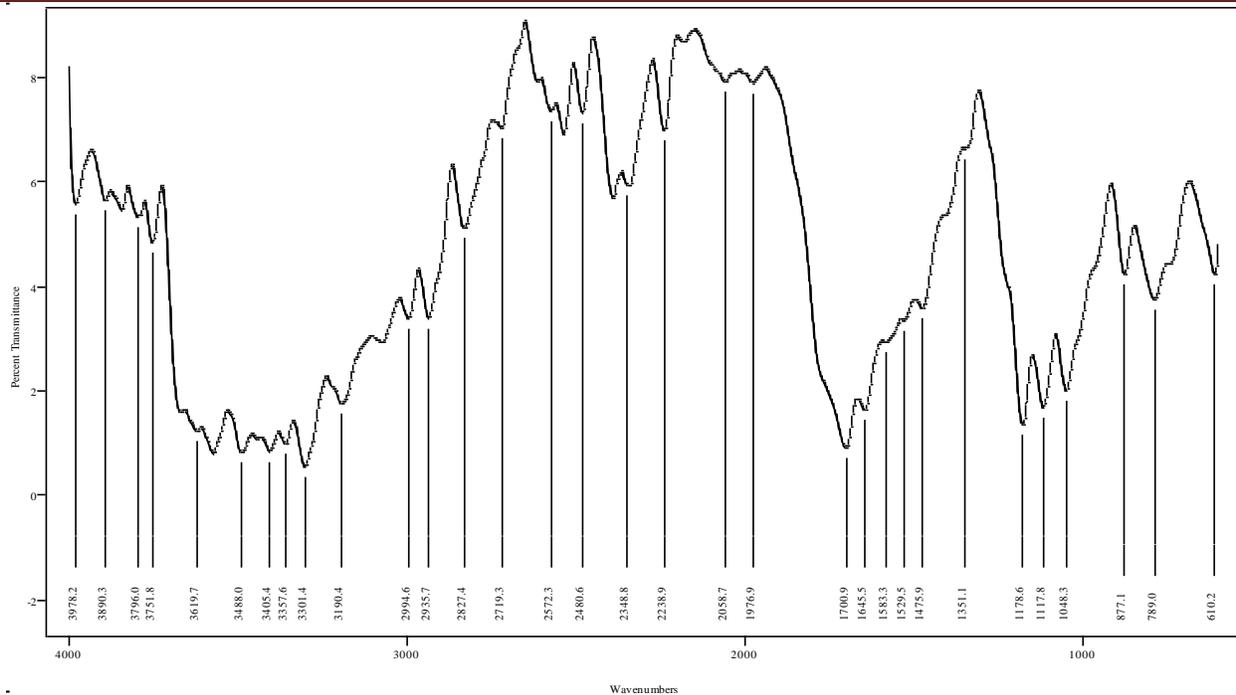


Fig. 2: FTIR analysis showing peaks, wavelength and peak heights

3.2 Braummer-Emett-Teller (BET) analysis

BET analysis was done to show the surface area of the CBAC sample. The result which was obtained in a multi-point BET plot shows that the surface area of the CBAC sample is $593.27m^2/g$.

The other properties obtained from the analysis is shown in Table 3 and the graphical representation in Fig.3.

Table 3. Result from BET analysis showing properties of CBAC

Properties	Result
Adsorption energy / kJ/mol	3.998
Average pore width / nm	6.503
Micro pore volume / cm^3/g	0.212
Micro pore surface area / m^2/g	595.558
Surface area / m^2/g	593.270
Pore diameter / nm	3.000
Pore volume / cm^3/g	0.152
Langmuir surface area m^2/g	1.38e+04

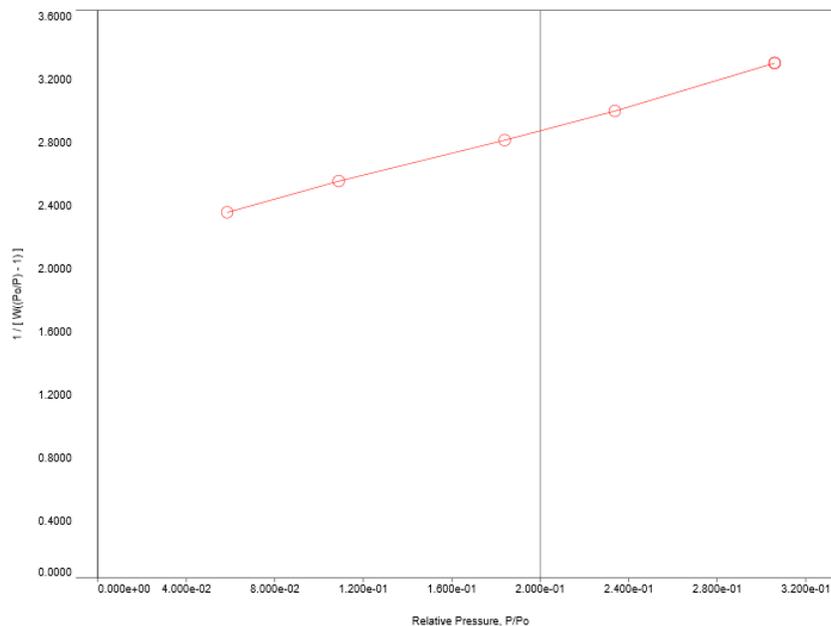


Fig.3: Multi-point BET plot

3.3 Scanning electron microscope (SEM) analysis

SEM analysis was performed to establish the surface morphology and pore diameter distribution of the CBAC adsorbent. The result of the analysis is shown in Fig. 4, The morphology of the CBAC was observed to have irregular shapes and sizes with little pores for particle attachment.

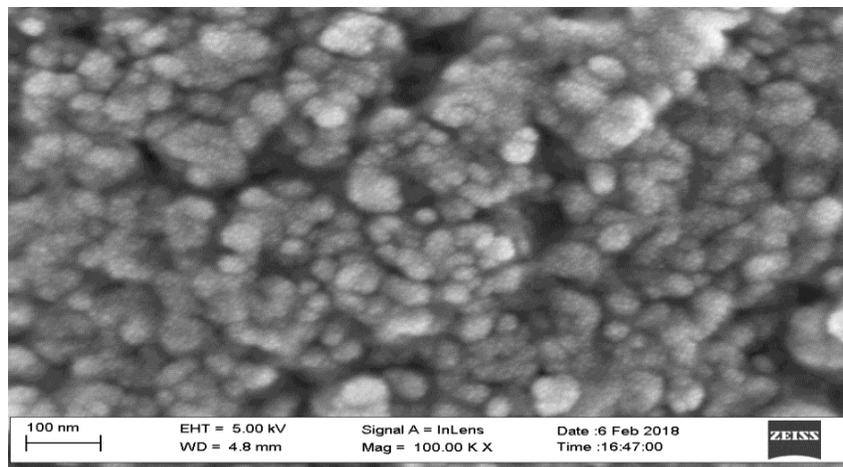


Fig. 4: SEM analysis of CBAC

3.4 Regression Model Equation

A least-squares fit of a model to the experimental data was constructed and the developed model correlated the response to the process variables using second degree polynomial [16]. The selected model was based on the highest order model where the additional terms were significant and the model was not aliased and there was reasonable agreement between Adjusted R^2 and predicted R^2 . The coded predictive model was presented in Eq.2. To identify the relative significance of the factors, the coefficients of the factors are compared from the coded equation. Based on the experimental design and results obtained, the second order response functions of Eq.2 was obtained. Y is the output variable, X_1 , adsorbent dosage (g), X_2 , adsorption time (mins) and X_3 as the coded value of variable temperature ($^{\circ}\text{C}$). From the model equation and P-value in table 4, time is the most significant effect on the bleaching performance.

$$Y = +25.242 - 0.576 * X_1 + 1.187 * X_2 + 0.228 * X_3 + 0.000377 * X_1X_2 + 0.00462 * X_1X_3 - 0.000861 * X_2X_3 + 0.0190 * X_1^2 - 0.0109 * X_2^2 - 0.00113 * X_3^2 \quad (2)$$

3.5 Analysis of Variance (ANOVA)

Table 4 presents the result of ANOVA in which the Model F-value of 79.2 suggests the model is 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 such as main effects, interactions and quadratic effects (X_1 , X_2 , X_3 , X_1X_3 , X_1^2 , X_2^2 , X_3^2) are significant. In addition, the model did not show lack of fit and presented high coefficients of determination $R^2 = 0.861$ indicating that 86.1% of the variability was explained by the model shown in Table 2. The Pred R^2 of 0.861 reasonably agrees with the Adj R^2 of 0.85. Fig. 5a,b explain the closeness of the experimental and the predicted values.

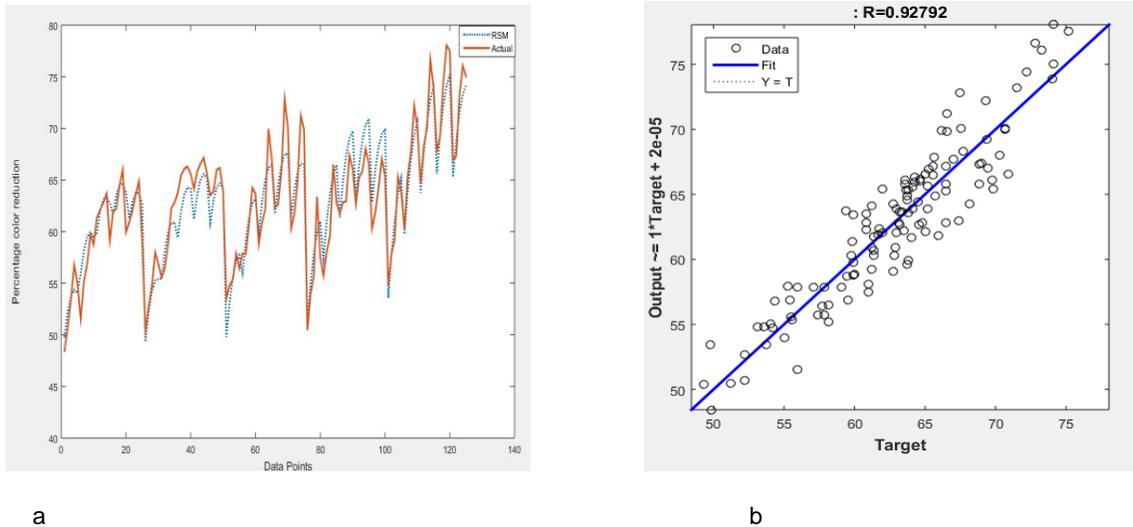


Fig. 5: Comparison of RSM model prediction against actual value of % color reduction.

3.6 ANN modeling

A neural network has been developed to model the adsorption process for the color removal efficiency for palm oil. The best topology of the ANN model includes three (3) inputs, one hidden layer with ten (10) neurons and one output layer (3-10-1) as shown in Figure 6. The best validation performance was captured at the 76th epoch out of the 82 model iterations with a value of 1.0415 as shown in Fig7. The coefficient of determination (R^2) for training, validation, testing and overall model presented in Fig.9 are reasonable, since the test set error and the validation set error have similar characteristics, and it does not appear that any significant over fitting has occurred. The network response analysis was carried out by utilizing a linear regression between the network outputs and the corresponding targets. The adequacy of the developed neural network model is demonstrated using the error histogram of Fig.8 and correlation plot of Fig.9. The resulting R^2 value of 0.987 signifies a reasonable correlation of all actual experimental data by the proposed model. Also, the error histogram of Fig. 8 demonstrated that the neural network models the system with great accuracy.

Table 4: ANOVA for palm oil bleaching

Source	Estimate	SumSq	Df	MeanSq	Fvalue	p-value
Intercept	25.242					
X ₁	-0.576	900.26	1	900.26	165.41	5.3079e-24
X ₂	1.187	1622	1	1622	298.01	1.0295e-33
X ₃	0.228	670.34	1	670.34	123.16	6.7655e-20
X ₁ X ₂	0.000377	0.17785	1	0.17785	0.032677	0.85687
X ₁ X ₃	0.00462	106.55	1	106.55	19.576	2.2086e-05
X ₂ X ₃	-0.000861	14.837	1	14.837	2.726	0.10145
X ₁ ²	0.0191	79.273	1	79.273	14.565	0.00021966
X ₂ ²	-0.0109	412.96	1	412.96	75.875	2.5857e-14
X ₃ ²	-0.00113	71.714	1	71.714	13.176	0.00042454
Error		625.91	115	5.4427		
No of obsv:125				R ² : 0.861, Adj.R ² : 0.85	Root Mean Squared Error: 2.33	F-statistic vs. constant model: 79.2, p-value: 4.42e-45

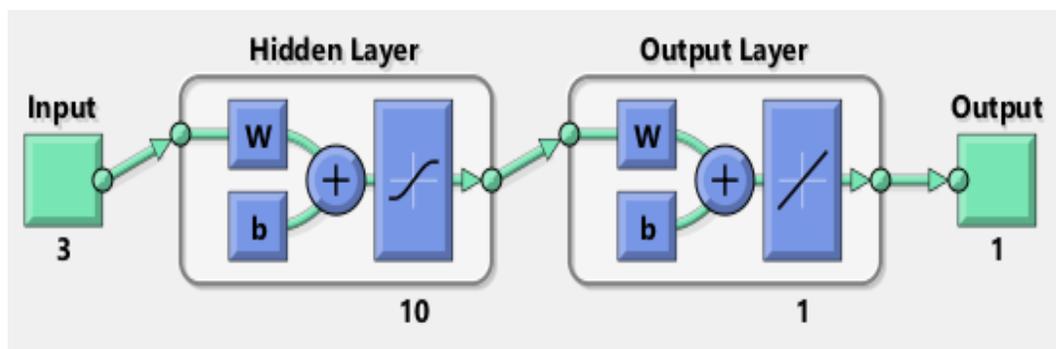


Fig.6: The proposed neural network architecture.

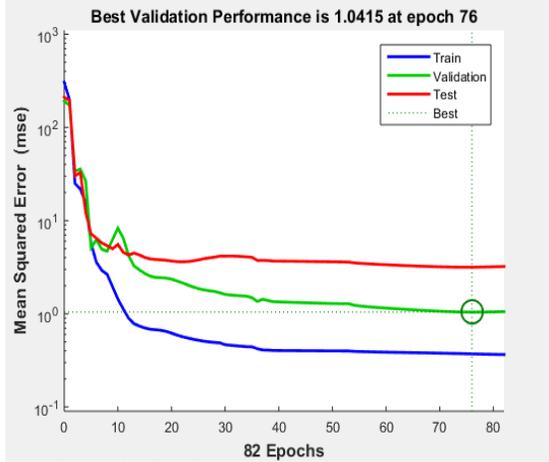


Fig. 7: Training performance of the ANN.

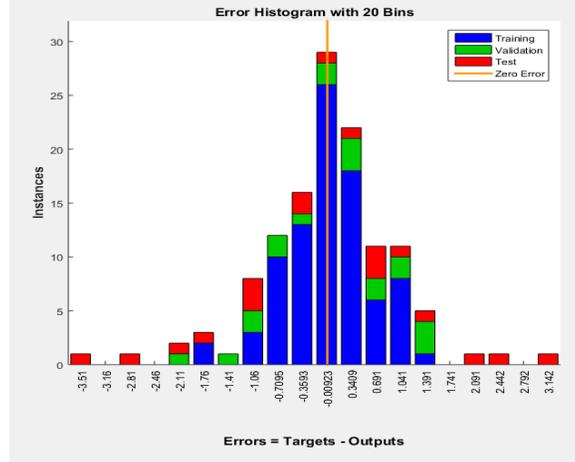


Fig. 8: Error histogram of the ANN model.

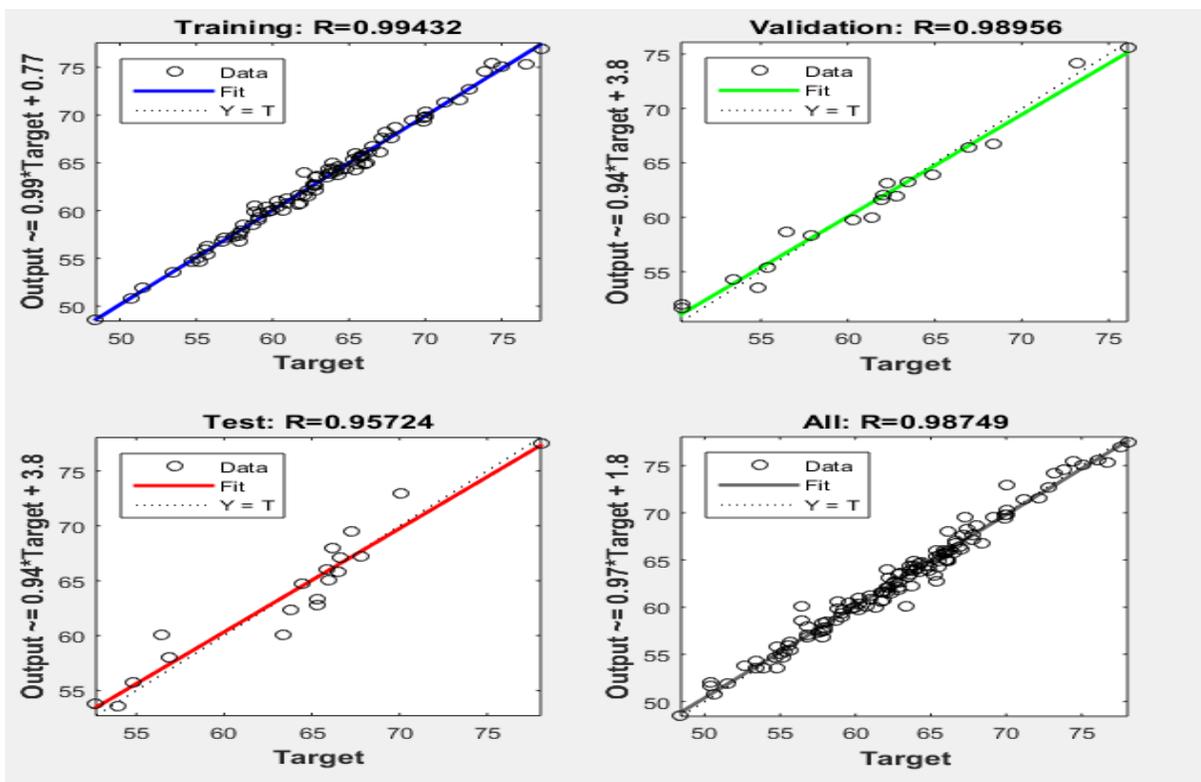


Fig. 9: Regression plots for training, validation, testing and overall ANN model.

3.7 Effects of process parameters on colour removal efficiency from RSM and ANN models.

The interaction effects of the process parameters on the percentage color removal from crude palm oil using animal bone activated carbon are discussed below. Figs. 10 a-f, show the contour (2D) plots and surface (3D) plots for the interaction effect between adsorbent dosage, adsorption temperature and time on the percentage color removal from crude palm oil using animal bone activated carbon. The volume of crude palm oil bleached was kept constant at 20ml throughout the experimental runs. Fig. 10a and 10b, demonstrate the effect of interaction between time and dosage on colour removal efficiency. As seen from the surface plots, interacting effect of the increased adsorbent dosage and adsorption time leads to an increment in percentage color removal up to an optimum point. The response was higher at high adsorbent dosage with longer adsorption time while at shorter reaction time and low adsorbent dosage, response was lower. The increase in the color removal efficiency of ABAC on crude palm oil as the dosage was varied from 5g to 25g and time from 20 minutes to 60 minutes was because of the increase in the number of active sites for adsorption and more interfacial

contact. This finding is also similar to the result reported by [17] where an increased adsorption was observed within variations of 1g to 4g for adsorbent dosage and 15 minutes to 60 minutes for time. The 3D response surface plots show that the highest response of 75.17% and 77.45% were captured at 25g adsorbent dosage and 50 minutes from RSM and ANN models respectively.

Temperature is known to affect oil viscosity and adsorption kinetics [18, 19]. Increasing temperature decreases oil viscosity which results to better dispersion of color particle, improved adsorbent oil interactions and flow ability. Figs. 10c-10f, illustrate the 2D and 3D plots for the temperature-adsorbent dosage interaction and temperature time interactions on the system response for the RSM and ANN models respectively. It was shown from Figs. 10c and 10d that the maximum color removal on ABAC was obtained when adsorbent dosage was 15g with a simultaneous increase in the adsorption temperature from both models. The surface plots showed that the effect of adsorbent dosage is only significant if it is coupled with the higher adsorption temperature. This can be as a result of increase in kinetic energy of the particles of the color pigment with increasing temperature. This increased kinetic energy of the color particles results in more frequency of collisions between the adsorbent and the color particles thereby enhancing the adsorption onto the surface of the adsorbent. This shows that, the combined effect of temperature and dosage have a relatively high impact on the color removal efficiency of ABAC on crude palm oil. The highest response was observed at 25g and 120°C from RSM model but 25g and 100°C from the ANN model. This finding could imply a possible decrease in color removal efficiency beyond a certain limit of temperature between 100°C and 120°C for animal bone activated carbon on crude palm oil.

Figs. 10e-f, demonstrate the impact of adsorption time and temperature on the system response. From the 2D plots of Figs. 10e and 10f, it was found that maximum colour removal was only in the range of 45-55 minutes, 100-120°C and hence there was negative impact of these interactions on the color removal efficiency. Relatively low bleaching efficiency is predicted for all short durations of bleaching cycles. Increasing contact time produces initial positive effect in tandem with improved color particle removal which was however reversed after optimum condition in line with the work by [20]. Generally, adsorption efficiency tends to decrease as the contact time increases well beyond 50 minutes, again due to progressive degradation of the adsorbent surface. In all, a combination of 50 minutes adsorption time and 120°C from the RSM model and 50 minutes adsorption time and 100°C from the ANN model were found to have optimal color removal effects by ABAC on crude palm oil. In summary, by suitable selections of the input parameters range at their mean values; adsorbent dosage: 25g, temperature: 100°C and time: 50 minutes, the response parameters of percentage color removal from crude palm oil using ABAC can be maximized.

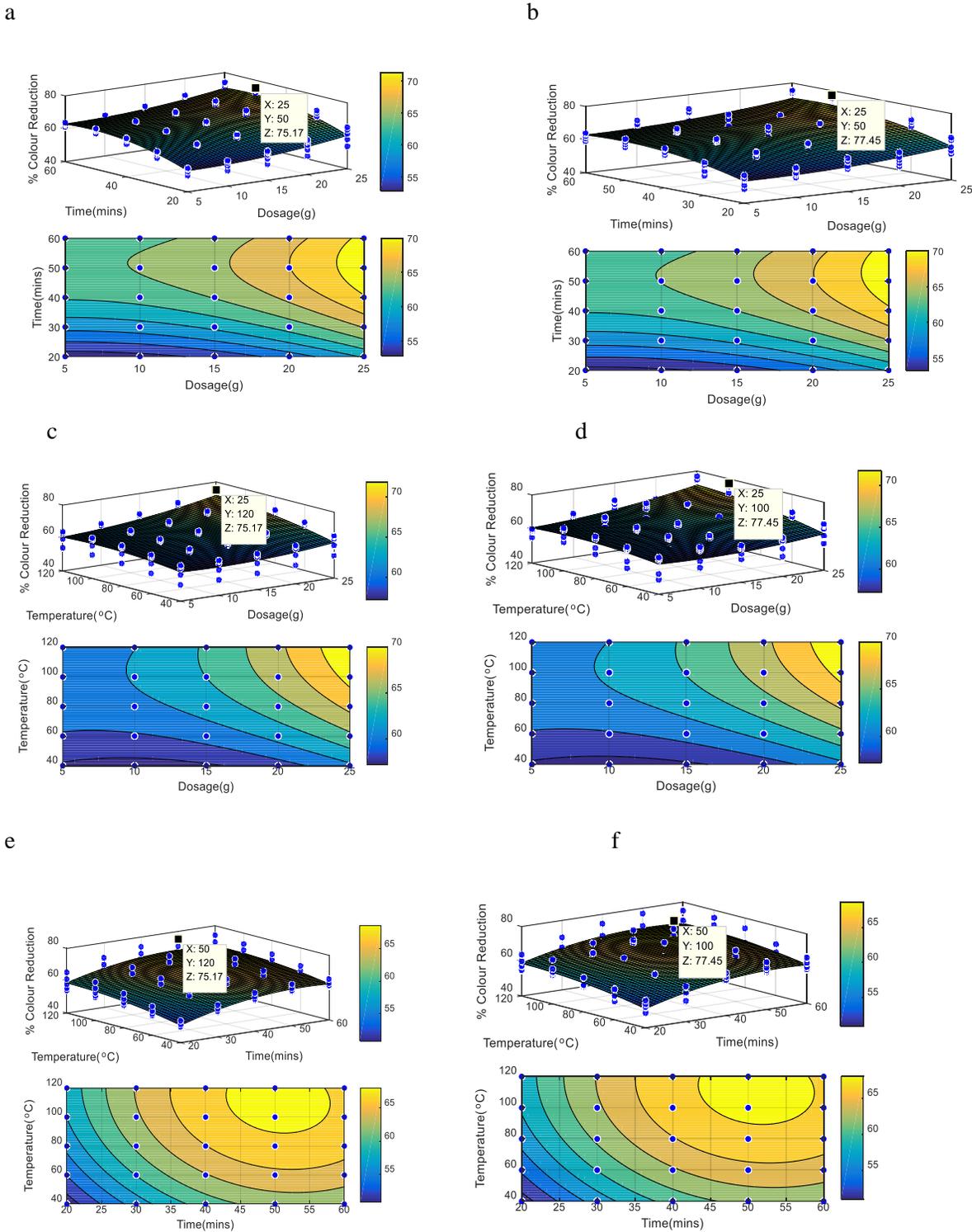


Fig. 10: 2D contour and 3D surface plots for interaction effects predicted by RSM (a,c,e) and ANN (b,d,f) models.

3.8 Optimization studies using RSM and ANN-GA.

To optimize the RSM results, different combinations of the operating variables were explored, while GA was used to tune the ANN results to optimize the percentage colour reduction from the adsorption process. A surface plot of interaction was applied to view the interaction effects of the three process variables for the models. The reaction parameters; adsorbent dosage, temperature and time, were analyzed from the surface and contour plots, as shown in Figs. 10a-f, and are summarized for the optimal parameters to obtain maximum colour removal efficiency as proposed by the two models. Using statistical data, the optimal adsorption parameters were estimated as 25g adsorbent, 50 minutes, 120°C for a 75.17% colour removal from the RSM model and 25g adsorbent, 50 minutes, 100°C for a 77.45% colour removal from the ANN model. This estimation was further considered for probable optima using a hybrid Artificial Neural Network Genetic Algorithm (ANN-GA) and had maximum yield. To predict the percentage color reduction response with improved accuracy, GA is applied to tune the neural network prediction data and find the optimum parameters. GA algorithm was used to remove the shortcoming of the local optima trapping which is a characteristic of least square tuning technique of the variables. The root-mean-squared error (RMSE) acts as an objective function of ANN-GA algorithm. Hybrid ANN-GA model was developed to extract the benefits of each of two individual tools so that the developed model can even perform more efficiently. Optimum conditions which guaranteed maximum 92.31% color reduction were selected after observing the results of the GA (Fig. 11). The optimized conditions were obtained as follows; 25g adsorbent dosage, 46mins adsorption time and 104.32°C adsorbent temperature.

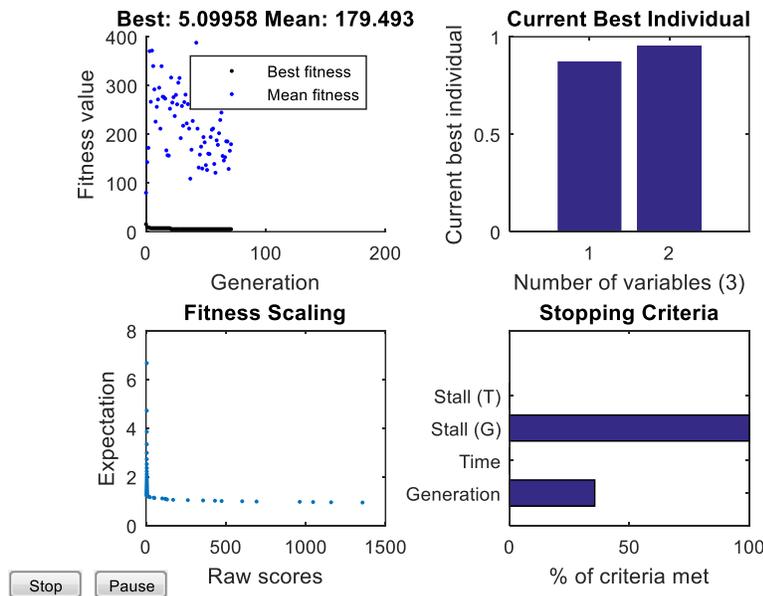


Fig. 11: GA optimisation results.

3.9 Comparative predictive and optimal evaluation of ANN and RSM

To determine the efficacy of the developed RSM and ANN models, statistical analysis was employed. The ANN gave a regression coefficient (R^2) value of 0.987, while that of RSM was 0.861. This shows that ANN can account for more than 98.7% of the variability in the system while RSM can only account for 86.1% for the system. The ANN model shows good fitting with the experimental data and gave better performance than RSM as seen from the results. The comparative plot for the experimental and the predicted value of percentage colour reduction is plotted for both models as shown in Fig. 12 from whence perfect fit between the experimental and predicted value for the ANN than the RSM model can be clearly observed. From the plot, it can be seen that all the predicted values are near to the line and the percentage colour reduction predicted by ANN is observed to be closer to the actual data obtained from the laboratory when compared to that predicted by RSM. Since the ANN was built up from the experimental results of RSM, its prominence is sure to be

certain. RSM gave an optimal colour reduction of 75.17% at 25g, 50 mins and 120°C, while the ANN-GA gave 92.31% at 25g, 46 mins and 104.32°C. It can be concluded that ANN-GA interface is 18.57% more efficient than RSM in trapping the optimal.

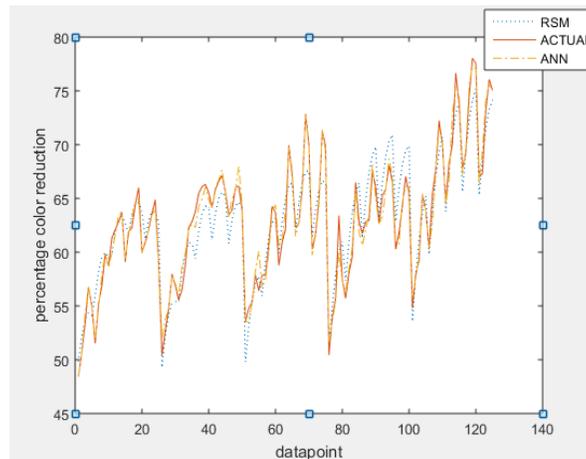


Fig. 12: Comparative plot of actual and predicted values for RSM and ANN models

Conclusion

This research work has established a non-toxic, low cost, biodegradable ABAC well suitable for palm oil bleaching. An RSM based on FFD and a multi-layer neural network (3-10-1 ANN architecture) models were developed in order to model the system under study. The input variables were adsorbent dosage, time and temperature while the output was the percentage colour reduction. The efficiencies of the models were shown from the results of their performance evaluated by their coefficients of determination (R^2). The models showed that all the mentioned variables had a significant effect on the response (% colour removal). ANN showed more prominent prediction accuracy since it was built up from the experimental results of RSM. Whereas different combinations of the independent variables was applied for optimizing the RSM results, ANN results were used with GA to optimize the percentage color removal from palm oil. It was found that ANN is a powerful technique for prediction of the bleaching response using the operating parameters as the inputs. RSM gave an optimal yield of 75.17%, while ANN-GA gave 92.31% colour removal. It was established that ANN-GA interface was 18.57% more efficient than RSM in trapping the optima.

References

- [1] Abraham Lustgarten (2018), Palm oil was supposed to help save the planet, instead it unleashed a catastrophe. World Bank's palm oil strategy. New York Times.p.MM42 www.nytimes.com/2018/11/25.
- [2] Thomson Ayodele (2010), The World Bank's Palm oil Mistake, The New York Times.p.A19 www.nytimes.com/2010/10/16.
- [3] Isharq-Zubair, M.T, Pancras J.M, Steven A.N, Andreas S.G (2010): Using Trace Metals, Peroxide Acid and Iodine values from Central and Eastern Uganda, American Journal of Analytical Chemistry. 5,1302-1312. <https://dx.doi.org/10.4236/ajac.2014.517136>
- [4] Christidis, G.E and Kosiari, S (2003), Deodorization of vegetable oils:A study of the Mechanism of Adsorption of β -carotene by an Acid Activated Bentonite from Cyprus. Clays and Clay Minerals, 51, 327-333, <https://dx.doi.org/10.1346/CCMN.1979.0270310>
- [5] Sacks F.M, Lichtenstein A.H, Wu JHY, Appel LJ, Creager M.A ,Kris Etherton P.M, Miller M,(2017) Dietary Fats and Cardiovascular Disease. A Presidential Advisory from the American Heart Association. Circulation. 136(3), e1-e23, [doi.10.1161/CIR.PMD.28620111](https://doi.org/10.1161/CIR.PMD.28620111).

[6] Mozaffarian D, Clarke R (2009): Quantitative effects on Cardiovascular risk factors and coronary heart disease risk of replacing partially hydrogenated vegetable oils with other fats and oils. *European Journal of Chemical Nutrition*. 63 suppl.2:S22-23, doi.10.1038/sj.ejca.1602976PMD19424216

[7] Brown Ellie, Jacobson Michael F,(2005) *Cruel oil: How palm oil harms health, rainforest and wild life*, Center for science in the public interest, Washington D.C. pp iv, 3-5, www.cspinet.org ccLc 224985333.

[8] Kooli F, Depege C, Ennagadi A, (1997), Rehydration of Zn-Al layered Double Hydroxides. *Clays and clay minerals*. 45, 92-98. <https://doi.org/10.1346/ccMN.1997.0450111>.

[9] Falaras, P, Lezou, F, Seiragakis, G, Petrakis, D {2000}, Bleaching properties of Alumina-Pillared Acid-Activated Montmorillonite. *Clays and Clay minerals*, 48{5}, 549556. <https://doi.org/10.1346/CCMN2000.0480507>

[10] Wannahari R, Nordin M.F (2012), Reduction of peroxide value in used palm oil cooking oil using bagasse adsorbent., *American International Journal of Contemporary Research*, 2(1), 185-191. www.ajcnet.com.

[11] A.K Babayemi, O.D. Onukwuli, E.E Eluno, J.A Otolorin (2020), Optimizing process parameters of palm oil bleaching on locally prepared animal bone-based activated carbon using response surface methodology. *E QM, Winley*, doi:10.1002/toem.21729,

[12] A. Raza, F. Li, X Xu, J.Tang (2017). Optimization of ultrasonic assisted extraction of antioxidant polysaccharides from the stem of *Trapa quadrifida* using response surface methodology. *International Journal of biological macromolecules*, (94) 335-344

[13] E.Agcam, A. Alkydiz, V.M Balasubramaniam (2017), Optimization of anthocyanins extraction from black carrot pomace with thermosonication. *Journal of food chemistry*.vol.237, <https://doi.org/10.1016/j.foodchem.2017.05.098>

[14] Z.H Tan, R Yang, K.Terale (2016). Synoptic meta- plasticity realized in oxide memristive devices. *Advanced materials*,(28)2,377-384.

[15] Y.C Wu, J.W Feng,(2018) Development and application of artificial neural network. *Wireless pers commun* 102, 1645-1656. <https://doi.org/10.1007/s1/277-017-5224-x>

[16] A.YAydar, N.Bagdathoglu, O.Koseoglu (2017), Effect of ultrasound on olive oil extraction and optimization of ultrasound assisted of extra virgin olive oil by response surface methodology *Grasas aceites*,68(2).<https://doi.org/10.3489/gya.1057162>

[17] Raji, W.A., Azike, R.U. and Ngubi, F.W. (2019) Optimization of Bleaching Process of Crude Palm Oil by Activated Plantain (*Musa paradisiaca*) Peel Ash Using Response Surface Methodology. *Open Journal of Optimization* , 8, 38-46. <https://doi.org/10.4236/ojop.2019.81004>

[18] Ofochebe, S.M. and Ozoegwu, C.G. (2014) ‘Optimisation of the sorption capacity of sulphuric acid activated IBUSA clay in palm oil bleaching using response surface methodology’, *Int. J. Experimental Design and Process Optimisation*, Vol. 4, No. 2, pp.166–182.

[19] R.O Ajemba, O.D Onukwuli,(2013), Adsorptive removal of colour pigment from palm oil using acid activated Nteje clay. *Kinetics, equilibrium and thermodynamics, Physiochem. Probl. Miner. Process.* 49(1), 369-382.

[20] Berbesi, R. (2006) Achieving optimal bleaching performance, *Oil Mill Gazetteer*, Vol.112