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Central Composite Design for the Sorption of Crude Oil by Acetylated Pineapple Peel Fibers

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ABSTRACT

Oil spillage contamination is a growing environmental concern that harms both terrestrial and aquatic ecosystems, and its clean-up by sorption is an attractive method due to its simplicity and low cost. Extra benefit is accrued when the sorption material utilized is an agricultural waste. In terms of price, environmentally sustainable products and abundance, pineapple peel is an appealing sorbent for this purpose, and chemical modification by acetylation was performed to improve its oil sorption capacity. To determine preliminary ranges of variables in the sorption process, A two-level, four-factor central composite design (CCD) in response surface methodology (RSM) was utilized to analyze the effect of the four process variables namely adsorbent dosage (1.5- 3.5 g), initial oil concentration (25 – 75 g/L), contact time (10-30 min) and temperature (25 °C – 45 °C) on the oil sorption capacity. Based on the design, a total of 30 sorption experiments were performed and a quadratic model was developed linking the process factors to the response. From the analysis, the interaction plot and cube plot showed higher sorption capacities of the treated (acetylated) compared to the raw fibers. Results from the Analysis of variance (ANOVA) also indicated that the model of the treated fibers was more adequate than the raw fibers.

1. INTRODUCTION

Oil spills are considered to be one of the major sources which contribute to environmental contamination and damage as it threatens the public health, destroys natural resources and disrupts the economy (King *et al*., 2015). Compared to other sources of pollution, oil has the characteristic of quick spreading on the surface of the water and covering large areas forming air insulation that threatens the aquatic life (Saadoun, 2015). Crude oil contains various toxic chemicals such as human carcinogens, and long-term health effects including the development of cancer and degenerative diseases from such exposure could result in a substantial burden of disease on the exposed population (Fingas, 2016).

Sorption has been recognized as one of the most efficient methods in recent decades for the complete removal of spilled oil under ambient conditions (Bandura *et al*., 2017), with natural fibrous based sorbents gaining increasing interest due to its inherent advantages like decontamination capability, good surface oil recovery possibility and capacity characteristics, perfectly-managed, less hazardous and inexpensive (Hoang *et al*., 2018). However, these natural sorbents in general possesses low hydrophobicity which limits their oil sorption abilities (Teli and Valia, 2016). Hydrophobicity of natural cellulosic materials can be improved by chemical modifications such as acetylation treatment which can impart the ability to absorb higher amount of oil than the unmodified fibers (Viju *et a*l., 2019). By acetylation, the polymer hydroxyl groups of the cell wall are being substituted with acetyl groups, modifying the properties of these polymers so that they become hydrophobic.

Response surface methodology (RSM), a powerful optimization method, has been widely used to analyze the most effective process conditions in the presence of fewer experimental data. (Sugashini *et al*., 2013). Among the reasons for its popularity are the fact that it does not require the consumption of extra chemicals for each parameter, it is less time-consuming, less cost- and labor-intensive (Şahan and Öztürk, 2014) and it overcomes the deficiencies of single factor optimization (Aghaeinejad-Meybodi *et al*., 2015; Kakelar and Ebrahimi, 2016). Using RSM substantially reduces the number of experiments necessary to predict the conditions for best performance (Kumar *et al*., 2013; Jentzer *et al*., 2015). Furthermore, the process refines the interpretation of complex phenomena and provides a basis for process scaling (Alkhatib *et al*., 2016).

To analyze the process variables for the sorption process, the combined effect of adsorbent dosage, contact time, initial oil concentration and temperature were analyzed using a central composite design in response surface methodology (RSM) using Design expert software version 6. Thus, the aim of this study is to model and analyze the sorption of spilled crude oil using pineapple peel fibers by response surface methodology, and to evaluate the effect of acetylation of the pineapple peel fibers on the oil sorption capacity. This is geared towards providing a suitable and more efficient way of oily waste water treatment.

2. MATERIALS AND METHODS

2.1. Material Collection and Preparation

Pineapple peel fibers were collected from fruit sellers in Sabon Gari local government area of Kaduna State, Nigeria. The samples were thoroughly washed with distilled water to remove foreign materials and water-soluble components. The washed samples were initially air dried for 12 hrs and then oven-dried to a constant weight at 65 °C for 36 hrs. The samples were then cut, ground into powder and sieved with laboratory sieves to obtain homogenous particle sizes using a mechanical sieve shaker which was used to separate the sorbent into the desired particle size of 300 µm. To reduce the influence of the fiber extract on acetylation, the sieved materials were extracted with a mixture of acetone and n-hexane (4:1, v/v) as solvents for 5 hrs. The extraction was carried out to remove extractible components from the fibers. After extraction, the samples were dried in a laboratory oven for 16 hrs (Nwadiogbu *et al*., 2016).

2.2. Acetylation of the Pineapple Peel Fibers

A portion (20 g) of the sorbent was placed in a 250-mL conical flask containing 120 mL of acetic anhydride and 6 g (1% of the solvent) *N*-bromosuccinimide (NBS). The flask was placed in a temperature-controlled water bath set at 70 °C for 90 min, under atmospheric pressure. The conical flask was then removed from the water bath and the hot reagent was decanted. The sorbents were thoroughly washed with ethanol and acetone to remove unreacted acetic anhydride and acetic acid by-product. The products were allowed to dry in an oven set at 60 °C for 16 hrs and later cooled in a desiccator and stored in a plastic container prior to analysis and crude oil sorption studies (Onwuka *et al.,* 2016).

2.3. Central Composite Design

A face-centered central composite design (CCD) which is appropriate for fitting second degree polynomial equations was applied to study the factors for the oil sorption capacity by raw and treated pineapple peel fibers. Four factors which are important variables in the oil sorption process were selected for the study. The factors are adsorbent dosage, contact time, initial oil concentration and temperature. For a design of four independent factors (K= 4), each with two different levels, the total number of experiments (N) was calculated using:

$$N = 4^2 + (2 \times 4) + 6 = 30 \tag{1}$$

Having specified the range of each of the process factors, they were coded to lie at ±1 for the factorial points, 0 for the center points and ± for the axial points (Nkeng, 2017). The chosen process factors with their limits, units and notations are presented in Table 1.

Table 1: Process factors and levels considered for the oil sorption

Factors	Units	Symbol	Levels				
			-α	Low (-1)	Center (0)	High (+1)	+α
Adsorbent dosage	g	A	1.5	1.5	2.5	3.5	3.5
Contact time	min	B	10	10	20	30	30
Initial oil concentration	g/L	C	25	25	50	75	75
Temperature	ºC	D	25	25	35	45	45

The design had 30 experimental runs which comprised of 24 non-center points and 6 center points. Interactions between these factors were studied using the two variable interaction and the cube plots. Design expert software version 6.0 was used to generate the experimental runs and for the statistical analysis of the oil sorption process.

2.4. Oil Sorption Capacity (OSC)

The raw and acetylated samples were subjected to crude oil sorption test, and in order to simulate the situation of oil spill and minimize experimental variation, the crude oil sample was held in beakers for 1 day in open air to release volatile hydrocarbon contents. The experiments were carried out with variations of the four process factors including adsorbent dosage (1.5 – 3.5 g), contact time (10 – 30 min), initial oil concentration (25 – 75 g/L) and temperature (25 – 45 ºC) and were analyzed using the central composite design (CCD). The 30 experimental runs with the various combinations of the different factors were randomly performed according to Table 2.

To 1 liter of distilled water, a known concentration of crude oil was added. A known mass of the sorbent was added into the mixture in the beaker and left unperturbed at a known contact time in a water bath at a known temperature. After the contact time had elapsed, the sorbent was removed using sieving net and left to drain by hanging the net over the beaker in an oven for 4 hrs at 60 °C. The sorption capacity of the sorbent samples was calculated using the expression

$$\text{Oil sorption capacity} = \frac{\text{New Weight Gained (g)}}{\text{Original weight (g)}} \quad (2)$$

3. RESULTS AND DISCUSSION

3.1. Statistical Analysis

The fitness of the model was investigated using the analysis of variance (ANOVA) at 95% confidence interval. The ANOVA of the oil sorption capacity for the treated and untreated fibers is presented in Table 2 and 3. The analysis of variance (ANOVA) of the regression model revealed R2 value for treated pineapple peel fibers (TPPF) and untreated pineapple fibers (UPPF) as 0.9824 and 0.9284 respectively indicating that the model can explain 98.24% and 92.84 % of the data variation respectively and only 1.76% and 7.16 of the total variations were not explained by the model respectively. For a model to be adequate, R^2 value should not be less than 0.75 (Le Man et al., 2010). With the R^2 value of both treated and untreated PPF above 0.75, it indicates that the fibers had adequate models but treated PPF being more adequate in fitting the data. The significance and insignififance of each term were determined by the Fischer's F-test and P-value. Results presented revealed that all the fibers had quite large F-values, with treated PPF having higher F-valeus of 59.70 compared to untreated PPF of 13.89. This implies that though the model is significant, the treated fibers gave a better fit to the model than the untreated fibers.

Adequate precision (AP) is basically a measure of signal to noise ratio, ratios greater than 4 indicate that the model is adequate and can be used to navigate the design space (Jasbir *et al.*, 2018). In this study, treated and untreated PPF had AP values of 32.693 and 15.452. These AP values ratios indicate an adequate signal and thus the model can be used to predict the response. But with the models of treated PPF having higher A.P ratios than the untreated PPF, it means it would give a better prediction to the response. The coefficient of variation (CV) is the ratio of the standard deviation of the mean expressed as a percentage and it reflects the precision and reliability of the experiments and results. For a model to be considered reliable and reproducible, it must have a CV less than 10 (Kuehl, 2000). From the tables, treated and untreated PPF had CV values of 1.88 and 5.45 respectively. These showed that both sets of fibers had good precision and reliability but with the models of treated fibers having lower C.V values than the untreated fibers, it means it would give a better precision and more reliability compared to the untreated fibers.

The model equation for the oil sorption capacity of the treated pineapple peel fibers (TPPF) and untreated pineapple peel fibers (UPPF) are presented in Equations 3 and 4

$$\begin{aligned} OSC = {} & 11.62 + 0.86A + 0.19B + 0.82\,C - 0.56\,D - 0.47A2 + 0.24B2 + 0.41\,C2 - \\ & 0.80D2 + 5.000E\text{-}003AB - 0.14\,AC - 0.016\,AD + 0.061\,BC + 0.073\,BD - 0.18\,CD \end{aligned} \quad (3)$$

$$\begin{aligned} OSC = {} & 7.61 + 0.74\,A + 0.22\,B + 0.69\,C - 0.48\,D - 0.45A2 + 0.34\,B2 + 0.15\,C2 - 0.82 \\ & D2 + 0.059\,AB - 0.15\,AC + 2.500E\text{-}003\,AD + 0.078\,BC + 0.044\,BD - 0.15\,CD \end{aligned} \quad (4)$$

Where A, B, C and D are the adsorbent dosage, contact time, initial oil concentration and temperature respectively.

Results for the CCD response of the oil sorption capacity are presented in Table 4 and 5. Results showed that the highest oil sorption capacity for both raw and treated pineapple peel fibers was obtained at the 11th experimental run with a high level of adsorbent dosage (3.5 g), high level of contact time (30 mins), high level of initial oil concentration (75 g/L) and a low level of temperature (25 °C), while the lowest oil sorption capacity for both raw and treated pineapple peel fibers was obtained at the 20th experimental run with a low level of adsorbent dosage (1.5 g), low level of contact time (10 mins), low level of initial oil concentration (25 g/L) and a high level of temperature (45 ^{o}C). Results also revealed that the treated pineapple peel fibers had higher oil sorption capacity compared to the untreated pineapple peel fiber for every experimental run.

Table 2: ANOVA for the oil sorption capacity of treated pineapple peel fibers

Source	Sum of squares	DF	Mean square	F value	P value
Model	37.18	14	2.66	59.70	< 0.0001
A	13.42	1	13.42	301.62	< 0.0001
B	0.65	1	0.65	14.52	0.0017
C	12.19	1	12.19	273.95	< 0.0001
D	5.69	1	5.69	127.91	< 0.0001
A^2	0.58	1	0.58	13.13	0.0025
B^2	0.15	1	0.15	3.36	0.0867
C^2	0.44	1	0.44	9.80	0.0069
D^2	1.68	1	1.68	37.73	< 0.0001
AB	4.000E-04	1	4.000E-04	8.993E-03	0.9257
AC	0.31	1	0.31	7.05	0.0180
AD	4.225E-03	1	4.225E-03	0.095	0.7622
BC	0.060	1	0.060	1.35	0.2635
BD	0.084	1	0.084	1.89	0.1893
CD	0.52	1	0.52	11.65	0.0038
Residual	0.67	15	0.044		
Lack of Fit	0.67	10	0.067	2223.54	< 0.0001
Pure Error	1.500E-04	5	3.000E-05		
Cor Total	37.84	29			
Goodness of fit					
Std. Dev	0.21		R-Squared		0.9824
Mean	11.24		Adjusted R-Squared		0.9659
C.V	1.88		Predicted R-Squared		0.9201
PRESS	3.02		Adeq. Precision		32.639

Table 3: ANOVA for the oil sorption capacity of untreated pineapple peel fibers

Source	Sum of	DF	Mean	F value	P value
Model	29.44	14	2.10	13.89	< 0.0001
A	9.74	1	9.74	64.33	< 0.0001
B	0.84	1	0.84	5.58	0.0321
C	8.69	1	8.69	57.44	< 0.0001
D	4.12	1	4.12	27.21	0.0001
A^2	0.51	1	0.51	3.39	0.0853
B^2	0.31	1	0.31	2.03	0.1744
C^2	0.058	1	0.058	0.38	0.5451
D^2	1.74	1	1.74	11.52	0.0040
AB	0.055	1	0.055	0.36	0.5549
AC	0.38	1	0.38	2.50	0.1348
AD	1.000E-04	1	1.000E-04	6.606E-04	0.9798
BC	0.096	1	0.096	0.63	0.4380
BD	0.031	1	0.031	0.20	0.6593
CD	0.37	1	0.37	2.42	0.1408
Residual	2.27	15	0.15		
Lack of Fit	2.27	10	0.23	3243.31	< 0.0001
Pure Error	3.500E-04	5	7.000E-05		
Cor Total	31.71	29			

Goodness of fit			
Std. Dev	0.39	R-Squared	0.9824
Mean	7.14	Adjusted R-Squared	0.8616
C.V	5.45	Predicted R-Squared	0.6429
PRESS	11.33	Adeq. Precision	15.452

Table 4: Design matrix and response for the oil sorption capacity by the treated pineapple peel fibers

Run	Dosage (g)	Time (min)	Conc. (g/L)	Temp (^oC)	OSC TPPF (g/g) (Experimental)	OSC TPPF (g/g) (Predicted)
1	3.50	10.00	75.00	25.00	13.25	13.11
2	3.50	30.00	25.00	45.00	10.99	10.98
3	2.50	20.00	75.00	35.00	12.76	12.85
4	2.50	10.00	50.00	35.00	11.52	11.67
5	1.50	10.00	75.00	45.00	10.18	10.05
6	2.50	20.00	25.00	35.00	11.05	11.21
7	3.50	30.00	75.00	45.00	12.15	12.11
8	1.50	20.00	50.00	35.00	9.81	10.28
9	2.50	20.00	50.00	35.00	11.75	11.62
10	2.50	30.00	50.00	35.00	11.95	12.05
11	3.50	30.00	75.00	25.00	13.31	13.48
12	3.50	10.00	25.00	25.00	11.36	11.51
13	1.50	30.00	25.00	45.00	8.98	8.99
14	1.50	30.00	75.00	25.00	12.06	11.99
15	3.50	30.00	25.00	25.00	11.62	11.63
16	1.50	30.00	75.00	45.00	10.77	10.68
17	2.50	20.00	50.00	35.00	11.75	11.62
18	1.50	10.00	25.00	25.00	9.56	9.48
19	1.50	30.00	25.00	25.00	9.66	9.58
20	1.50	10.00	25.00	45.00	8.71	8.60
21	2.50	20.00	50.00	35.00	11.74	11.62
22	3.50	10.00	75.00	45.00	11.31	11.45
23	2.50	20.00	50.00	35.00	11.74	11.62
24	2.50	20.00	50.00	25.00	11.41	11.38
25	3.50	20.00	50.00	35.00	12.23	12.01
26	2.50	20.00	50.00	45.00	9.97	10.25
27	2.50	20.00	50.00	35.00	11.75	11.62
28	3.50	10.00	25.00	45.00	10.62	10.57
29	1.50	10.00	75.00	25.00	11.57	11.64
30	2.50	20.00	50.00	35.00	11.74	11.62

Table 5: Design matrix and response for the oil sorption capacity by the untreated pineapple peel fibers

Run	Dosage (g)	Time (min)	Conc. (g/L)	Temp (°C)	OSC UPPF (g/g) (Experimental)	OSC UPPF (g/g) (Predicted)
1	3.50	10.00	75.00	25.00	8.31	8.43
2	3.50	30.00	25.00	45.00	6.74	6.95
3	2.50	20.00	75.00	35.00	8.27	8.45
4	2.50	10.00	50.00	35.00	7.46	7.73
5	1.50	10.00	75.00	45.00	6.02	6.04
6	2.50	20.00	25.00	35.00	6.78	7.06
7	3.50	30.00	75.00	45.00	8.15	7.88
8	1.50	20.00	50.00	35.00	5.65	6.42
9	2.50	20.00	50.00	35.00	7.82	7.61
10	2.50	30.00	50.00	35.00	7.98	8.17
11	3.50	30.00	75.00	25.00	8.63	9.05
12	3.50	10.00	25.00	25.00	7.25	7.20
13	1.50	30.00	25.00	45.00	5.32	5.04
14	1.50	30.00	75.00	25.00	8.08	7.77
15	3.50	30.00	25.00	25.00	7.68	7.51
16	1.50	30.00	75.00	45.00	6.50	6.59
17	2.50	20.00	50.00	35.00	7.83	7.61
18	1.50	10.00	25.00	25.00	5.43	5.54
19	1.50	30.00	25.00	25.00	5.49	5.62
20	1.50	10.00	25.00	45.00	5.17	4.80
21	2.50	20.00	50.00	35.00	7.84	7.61
22	3.50	10.00	75.00	45.00	7.17	7.09
23	2.50	20.00	50.00	35.00	7.84	7.61
24	2.50	20.00	50.00	25.00	7.34	7.26
25	3.50	20.00	50.00	35.00	8.21	7.90
26	2.50	20.00	50.00	45.00	5.77	6.31
27	2.50	20.00	50.00	35.00	7.84	7.61
28	3.50	10.00	25.00	45.00	6.31	6.46
29	1.50	10.00	75.00	25.00	7.55	7.39
30	2.50	20.00	50.00	35.00	7.84	7.61

3.2. Effect of Interaction of two Variables on the Oil Sorption Capacity

3.2.1. Effect of the interaction of adsorbent dosage and contact time

The interaction effect of sorbent dosage and contact time on the oil sorption capacity is presented on Figures 1 and 2. Results in general showed that the interaction is significant between the both variables and that the interaction effect on the sorption capacity was higher in the treated (modified) sorbents than the untreated (raw) sorbents. Results for the treated sorbents showed that increasing the sorbent dosage at both high and low contact time produced an increase in the oil sorption capacities. The oil sorption capacity was highest in the interaction effect at high sorbent dosage and high contact time and this is as a result of enough time and more availability of binding sites for the sorption (Mousavi *et al.*, 2017). For the untreated fibers, results also showed that increasing the sorbent dosage at both high and low contact time also produced an increase in the oil sorption capacities but at a much lower level compared to the treated fibers.

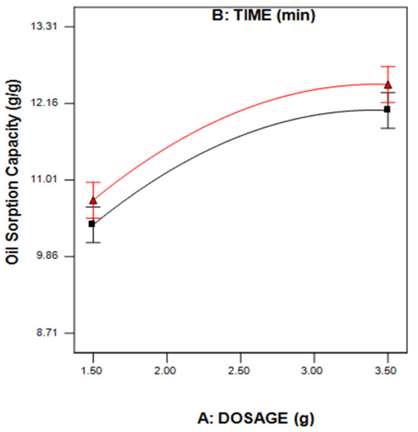

Figure 1: Interaction plot of adsorbate dosage and contact time for the oil sorption capacity of treated pineapple peel fibers

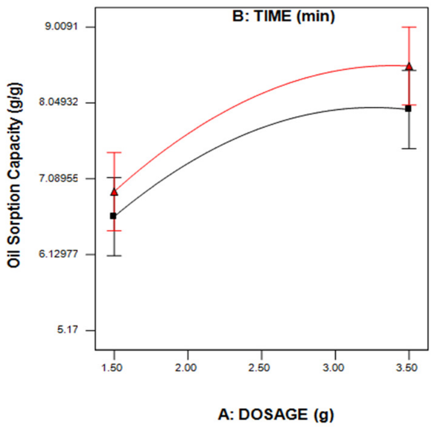

Figure 2: Interaction plot of adsorbate dosage and contact time for the oil sorption capacity of untreated pineapple peel fibers

3.2.2. Effect of the interaction of adsorbent dosage and initial concentration

The interaction plot showing the effect of adsorbent dosage and initial concentration on the oil sorption capacity is presented in Figures 3 and 4. For the treated fibers, results showed that there was a rapid increase in the oil sorption capacity when the adsorbent dosage was increased from 1.5 g to about 2.5 g for both concentration levels, and a steady increase in the oil sorption capacities after point until it reached maximum with the treated PPF having values of 13.10 g/g. The increase in the oil sorption capacity as the initial oil concentration and sorbent dosage increased could be because the initial oil concentration provided the necessary driving force to overcome the resistances to the mass transfer of oil between the aqueous and the solid phases (Ouasif *et al*., 2013) with more available sites for the oil to penetrate into the microscopic voids. For the untreated fibers, results also showed an initial rapid increase in the oil sorption capacity for both concentration levels (high and low) with increasing adsorbent dosage until when the adsorbent dosage was varied at 2.5 g, then a steady upward increase in oil sorption capacity with subsequent increase in adsorbent dosage.

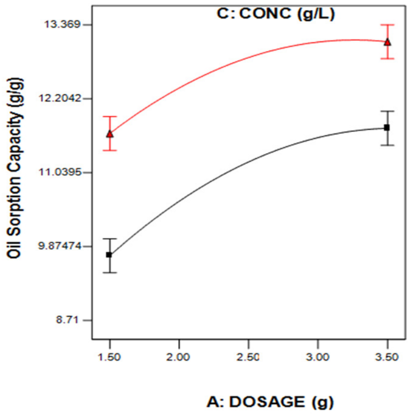

Figure 3: Interaction plot of adsorbate dosage and initial oil concentration for the oil sorption capacity of treated pineapple peel fibers

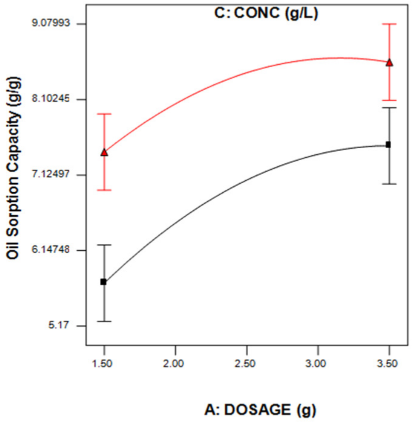

Figure 4: Interaction plot of adsorbate dosage and initial oil concentration for the oil sorption capacity of untreated pineapple peel fibers

3.2.3. Effect of the interaction of contact time and temperature

Presented in Figures 5 and 6 is the interaction plot showing the interaction effect of contact time and temperature on the oil sorption capacity. For the untreated fibers, results showed an initial decrease in oil sorption capacity with increasing contact time at both temperature levels with the sorption capacity decreasing more rapidly at higher temperature level than the low temperature level, and this could probably be due to the fact that at higher temperatures, oil starts to be very light which leads to its release from fibers and increase in the contact time may lead to more desorption from the fibers (Hussein *et al.*, 2009). Also, increasing the temperature may decrease the adsorptive forces between the oil molecules and the active sites on the adsorbent surface leading to a decreasing sorption capacity (Salleh *et al.*, 2011). For the treated fibers, there was an initial slight decrease then later a steady increase in the oil sorption capacities increase at both temperature levels at longer time intervals. This increase at longer contact time could be due to the increase of the rate of diffusion of the adsorbate molecules across the external boundary layer and the internal pores of the adsorbent particle (Gecgel *et al.*, 2013).

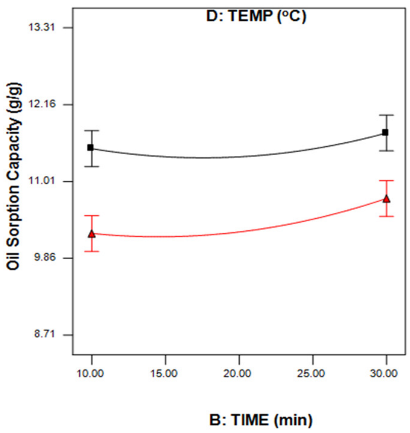

Figure 5: Interaction plot of contact time and temperature for the oil sorption capacity of treated pineapple peel fibers

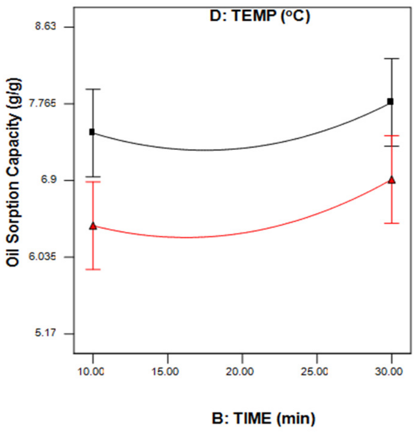

Figure 6: Interaction plot of contact time and temperature for the oil sorption capacity of untreated pineapple peel fibers

3.3. Effect of Interaction of three Variables on the Oil Sorption Capacity

3.3.1. Interaction effects of absorbent dosage, contact time and initial oil concentration

The cube plot for the effect of interaction of adsorbate dosage, contact time and initial oil concentration on the oil sorption capacity is shown in Figures 7 and 8. Results showed that interaction among the three factors for the treated fibers produced a higher oil sorption capacity compared to the untreated fibers. Results for both fibers (treated and untreated) indicated that increase in any of the factors resulted in an increase in the oil sorption capacity. The highest oil sorption capacity was achieved at the high factors of 3.5 g adsorbent dosage, 30 min contact time and 75 g/L initial oil concentration (A+, B+, C+) at 13.60 g/g and 9.28 g/g for the treated pineapple peel fibers (TPPF) and untreated pineapple peel fibers (UPPF) respectively while the lowest oil sorption capacity was achieved at the low factors of 1.5g adsorbent dosage, 10 min contact time and 25 g/L initial oil concentration (A-, B-, C-) at 9.85 g/g and 5.99 for the TPPF and UPPF respectively. This shows that all three factors were significant in influencing this interaction. It could be observed from the cube plot that the interaction factor of adsorbent dosage produced the most positive effect since all the highest oil sorption capacities were obtained at high adsorbent dosage thus increasing the uptake. This could be due to the fact that the internal porosity of the fibers also creates adsorption forces as well as an adsorption-surface area, these forces cause oil molecules to be adsorbed from the solution and deposited onto the molecule-sized pores and with an increase in the sorbents, there would be more increase in the oil sorption capacity (Adeyemo *et al*., 2017). The interaction among the three variables showed lower oil sorption capacities of the untreated fibers compared to the treated fibers.

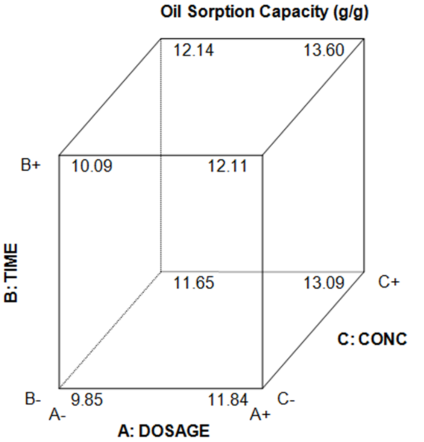

Figure 7: Cube plot of adsorbate dosage, contact time and initial oil concentration for the oil sorption capacity of treated pineapple peel fibers

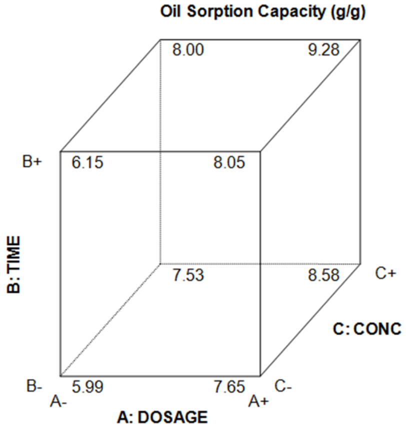

Figure 8: Cube plot of Adsorbate dosage, contact time and initial oil concentration for the oil sorption capacity of untreated pineapple peel fibers

3.3.2. Interaction effects of absorbent dosage, contact time and temperature on the oil sorption capacity

The cube plot for the effect of the interaction of adsorbent dosage, contact time and temperature on the oil sorption capacity is presented in Figures 9 and 10.

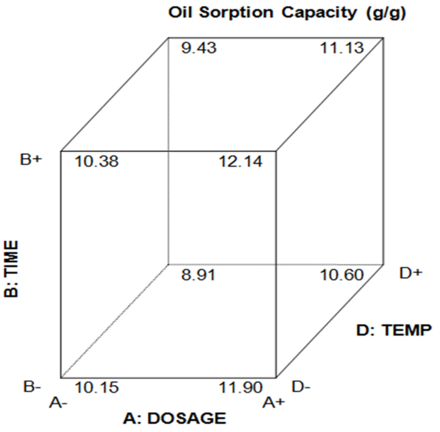

Figure 9: Cube plot of adsorbate dosage, contact time and temperature for the oil sorption capacity of treated pineapple peel fibers

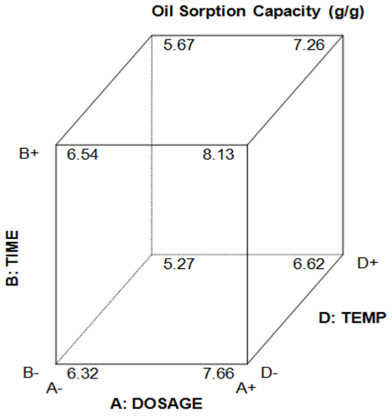

Figure 10: Cube plot of adsorbate dosage, contact time and temperature for the oil sorption capacity of untreated pineapple peel fibers

The plots showed that points where the temperature was high resulted in a decrease in the oil sorption capacity. The results showed that the highest value for treated PPF (12.14 g/g) was achieved at high adsorbent dosage of 1.5 g, high contact time of 30 min and low temperature of 25 ºC (A+, B+, D-). The role these factors played at the highest value could be due to the increased time taken for the penetration of the crude oil molecules into the many adsorption sites of the adsorbent, and at lower temperatures the oil molecules were less soluble in water making it easier to be adsorbed. The least value (8.91 g/g) was achieved at low adsorbent dosage of 1.5 g, low contact time of 10 min and high temperature of 45 ºC (A-, B-, D+). For the untreated pineapple peel fibers, similar results also followed in the interaction among the three variables but their oil sorption capacities were lower compared to the treated fibers.

4. CONCLUSION

In this study, Pineapple peel fibers were acetylated and assessed as a potential sorbent for crude oil spill cleanup. During the sorption process, four factors (adsorbent dosage, contact time, initial oil concentration and temperature) were analyzed with the help of CCD and oil sorption capacity as the analyzed response. Based on the results of the analysis, the oil sorption capacity by both raw and treated pineapple peel fibers increased with increase in adsorbent dose, contact time, initial oil concentration and decreased with increase in temperature, with the sorption capacities of the treated fibers generally higher than the untreated (raw) fibers. The interaction plot and cube plot showed significant interaction among the variables and higher sorption capacities of the treated (acetylated) compared to the raw fibers. From the analysis, the treated fibers' coefficient of determination (R^2) values of 0.9824, F-values of 59.70, A.P of 32.693 and C.V values of 1.88 are indicative that the model is more adequate and reliable compared to the untreated fibers. Finally, the reported results in this study portrayed the feasibility of utilizing the central composite design model to analyze the experiments for the sorption of crude oil using acetylated pineapple peel fibers as a low- cost sorbent.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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