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PRELIMINARY STUDY OF RESPONSE SURFACE METHODOLOGY FOR OPTIMIZATION OF OIL REMOVAL BY ADSORBENT-BASED PINEAPPLE PEEL WASTE

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Abstract

The developing of oil industry these days caused the increasing of oil pollution. Hence, studies have been carried out to improve the environment through natural resources as an adsorbent to manage oil pollution. Pineapple peel waste was used in this study as the adsorbent in removing cooking and lubricant oil wastes in aqueous solution. The experimental design using response surface method (RSM) was applied to determine the optimum conditions such initial dosage of adsorbent, volume of oil and soaking time. The initial amounts of adsorbent used in the experiment were 0.2 g, 0.6 g and 1.0 g with different soaking time of 40 minutes, 25 minutes and 10 minutes. The volumes of oil used in this experiment were 5 mL, 17.5 mL, and 30 mL. The optimum conditions of cooking oil adsorption were 39.97 minutes for contact time, 0.61 g for adsorbent dosage and 29.96 mL for volume of oil and the percentage of oil adsorption calculated at these conditions was found to be 357.468 % while the optimum conditions of lubricant oil adsorption were 39.48 minutes for contact time, 0.20 g for adsorbent dosage and 5.03 mL for volume of oil. The percentage of oil adsorption calculated at these conditions was found to be 755.498 %. From the result, it showed that pineapple peel waste can adsorb both cooking oil and lubricant oil wastes.

Keywords: Cooking oil; Lubricant oil ; Adsorption; Response surface method; Oil pollution;

1.0 INTRODUCTION

Over the years, oil spill contaminations has become a major hazard to the environment especially the marine areas thus drawing vast consciousness to the researchers as it is an appalling problem that set both the marine life and ecosystem at atrocious danger [1]. The term 'oil spill' is usually applied to marine oil spills, where oil is released into the ocean or coastal waters when oil is manufactured, stored, and shipped but spills may also occur on land. If oil is explored, transported, stored and used too widely, the space to spill it will cause a severe problem and impose serious damage on the environment [1]. Oil spills may be caused by the release of crude oil from offshore platforms, tankers, drilling rigs and wells, fuels used by large ships such as bunker fuel, or the spill of any oily byproduct or waste oil by household. This affects the cleanliness and allure of the ocean or coastal waters, and the survival of the marine life. Regardless of the optimum efforts to control oil spill, it is not impossible for the oil to pollute shorelines of the ocean and reservoirs, and the edges of watercourses and brooks. To assist in preserving these water resources from destruction for our future generation and for the sustainability of various marine species, the cleanup of the water resources especially the ocean is crucial. Thus, a well-organized system is extremely vital for the retrieval of the spilled oil.

Several natural processes and physical methods, for instance, mechanical extraction, in situ combustion and chemical degradation have been used to the cleanup of oil from polluted areas [2]. Owning to better economic and environmental benefits, the use of the sorbent is considered as an effective method to concentrate, transfer, and absorb spilled oil [3]. The application of natural sorbents to clean up oil spill in an eco-friendly and cost effective way is favorable, and more attention should be paid to this prospect [1]. High-efficient oil sorbent is required to possess desirable characteristics, such as excellent hydrophobicity and oleophilicity, high uptake capacity, fast oil sorption rate, low cost, and high buoyancy. Inexpensive oil sorbents with advantageous oil-sorption properties are in need. In this case, the utilization of renewable resources as agricultural products and waste is much more notable due to their great sorption capacity, high biodegradability and low cost [2].

In this research, pineapple peel waste has been chosen to be a low cost and eco-friendly adsorbent in removing oil spill. The focus of this study is on the optimization of adsorption conditions such initial dosage of adsorbent, volume of oil and soaking time using response surface methodology (RSM).

2.0 EXPERIMENTAL

Adsorbent

Fresh pineapple that bought from market was peel off. The peels were washed and chopped into small pieces. The peels were dried under direct sunlight for 5 hours and 30 minutes in air oven at 60 °C. Dried pineapple peels were weighed using an analytical balance (Perkin Elmer USA) and was placed in 1000 mL beaker. The pineapple peels were then soaked into a solution (10% of sodium hydroxide ($NaOH$) (1.0 M) and 90% of deionized water) for 3 hours at room temperature. The samples were then rinsed with distilled water and soaked with acetic acid for 30 minutes at room temperature to neutralize the sample [4]. The treated samples were ground using mechanical grinder and were sieved to get the finest powder for the next step of the experiment.

Oil adsorption studies

Cooking oil and lubricant oil waste were used in this study as an adsorbate. Batch adsorption studies were performed to evaluate the pineapple peel powder for the removal of oil from aqueous solution. The effect of adsorption dose, volume of oil and soaking time were investigated.

The percentage removal of oil at equilibrium was calculated based on common equilibrium equation.

Design of experiments

The optimization of the removal of cooking and lubricant oil waste were designed using RSM with the application of the central composite design (CCD) using the Design-Expert® 6.0.10 software (Stat-Ease Inc. Minneapolis USA). In this study, the interaction between three variables (contact time, dosage and volume of oil) was measured using RSM. The variable was coded each at three levels; high (+1), middle (0) and low (-1). Table 1 shows the levels and factors variable in this experimental design.

Table 1. Levels and factors variables in the experimental design

Factors	Units	Code levels		
		+1	0	-1
Time	minutes	40	25	10
Dosage	g	1	0.6	0.2
Volume of Oil	mL	30	17.5	5

The total number of design experiments was 20 with 3 factors and six replications at the design centre to assess the pure error. The cubic model was choosing for this optimization.

3.0 RESULTS AND DISCUSSION

Tables

Experimental results with Design-Expert® 6.0.10 software. The interaction of this three important variables and oil removal was determined using polynomial regression. Based on the Design-Expert® experiment, the percentage of oil adsorption was in the range of 19.5% to 341.18% for cooking oil and 37.00% to 752.0% for used lubricating oil. These can be found in Table 2 and Table 4. The X1, X2 and X3 represent time, dosage and volume of oil in this study.

Table 2. The central composite design (CCD) using the Design-Expert® 6.0.10 software (Stat-Ease Inc. Minneapolis USA) result for cooking oil adsorption.

Run no.	Factors			Design-Expert® experiment (%) Oil Removal
	X1	X2	X3	
1	10.00	1.00	5.00	24.40
2	25.00	0.60	30.00	111.30
3	25.00	0.60	17.50	72.17
4	40.00	0.20	30.00	197.00
5	25.00	0.60	30.00	111.30
6	40.00	1.00	5.00	41.80
7	25.00	0.60	17.50	72.17
8	25.00	0.60	17.50	72.17
9	10.00	0.20	30.00	84.00
10	40.00	0.20	5.00	118.00
11	10.00	1.00	30.00	87.20
12	40.00	0.60	17.50	341.18
13	40.00	1.00	30.00	143.70
14	25.00	0.60	17.50	72.17
15	25.00	0.60	17.50	72.17
16	25.00	1.00	17.50	59.50
17	10.00	0.60	17.50	49.83
18	25.00	0.20	17.50	19.50
19	10.00	0.20	5.00	28.50
20	25.00	0.60	17.50	72.17

Table 2 shows the efficiency of the oil removal properties of the pineapple peel waste using different factors namely time, dosage of adsorbent and volume of oil. The ANOVA result was used to further emphasize the adequacy of the model and their significance.

The predicted and experimental optimum conditions of the maximum percentage of oil adsorption of pineapple peel waste and the process variables were shown in Table 3. The optimum condition was selected based on the higher value of model desirability were shown in figure 2. The optimum conditions for maximum percentage for cooking oil adsorption of pineapple peel waste were 39.97 minutes for contact time, 0.61 g for adsorbent dosage and 29.96 mL for volume of oil and the percentage of oil adsorption calculated at these values found to be 357.47%. The desirability was 1.00. The experimental value calculated was 312.13%, lower than the predicted value. This can be due to technical error during the experiment.

The three dimensional views of response surface plots for removal of cooking oil in cubic model was shown in figure 2. This figure visualized the interaction effect process variables for the percentage of oil removal in aqueous solution.

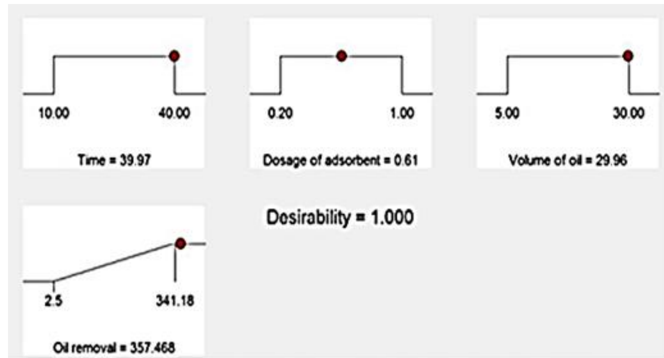

Fig. 1. Optimum conditions for maximum percentage for oil removal of adsorbent-based pineapple peel waste and cooking oil.

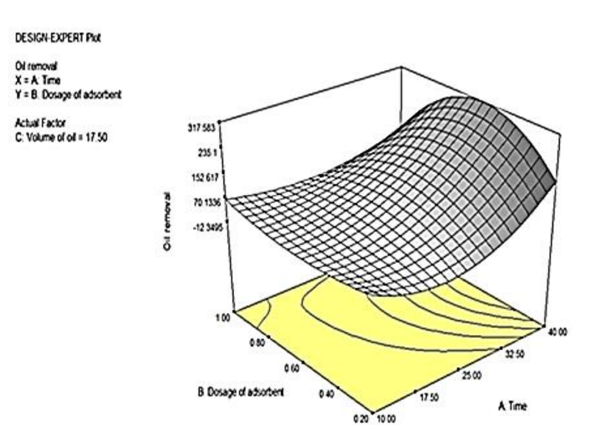

Fig. 2. Response surface for cooking oil removal as a function of dosage, time and oil volume in cubic model.

Table 3. Model validation for oil adsorption.

Time of contact (minutes), X1	Adsorbent dosage (g), X2	Volume of oil (mL), X3	Percentage of oil adsorption (%)	
			Predicted	Experimental
39.97	0.61	29.96	357.468	312.13

The experiment was then repeated using used lubricating oil. Based on the experiment, the percentage of oil adsorption was in the range of and 37.00% to 752.0% for used lubricating oil. These can be found in Table 4.

Table 4. Oil adsorption using pineapple peel and used lubricating oil.

Run no.	Factors			Predicted (%) Oil Removal
	X1	X2	X3	
1	10.00	1.00	5.00	457.20
2	25.00	0.60	30.00	494.83
3	25.00	0.60	17.50	358.83
4	40.00	0.20	30.00	37.00
5	25.00	0.60	30.00	494.83
6	40.00	1.00	5.00	391.50
7	25.00	0.60	17.50	358.83
8	25.00	0.60	17.50	358.83
9	10.00	0.20	30.00	47.50
10	40.00	0.20	5.00	752.00
11	10.00	1.00	30.00	107.70
12	40.00	0.60	17.50	414.50
13	40.00	1.00	30.00	396.70
14	25.00	0.60	17.50	358.83
15	25.00	0.60	17.50	358.83
16	25.00	1.00	17.50	416.90
17	10.00	0.60	17.50	357.33
18	25.00	0.20	17.50	464.50
19	10.00	0.20	5.00	380.50
20	25.00	0.60	17.50	358.83

From Table 4, it can be said that used lubricating oil is adsorbed in a greater scale compared to the cooking oil in Table 2. This can be explained by the difference of viscosity of the cooking oil and the used lubricating oil. Other than that, the different number of carbon contains in each type of oil can also effect the oil adsorbent rate [5].

The predicted and experimental optimum conditions of the maximum percentage of oil adsorption of pineapple peel waste and the process variables are shown in Table 5. The optimum condition (figure 3) was selected based on the higher value of model desirability. The optimum conditions for maximum percentage for oil adsorption of pineapple peel waste were 39.48 minutes for contact time, 0.20g for adsorbent dosage and 5.03mL for volume of oil and the percentage of oil adsorption calculated at these values found to be 755.498%. The desirability was 1.00.The experimental value calculated was 703.17%, lower than the predicted value. This can be due to technical error during the experiment.

The three dimensional views of response surface plots for removal of lubricant oil in cubic model was shown in figure 4. This figure visualized the interaction effect process variables for the percentage of oil removal in aqueous solution.

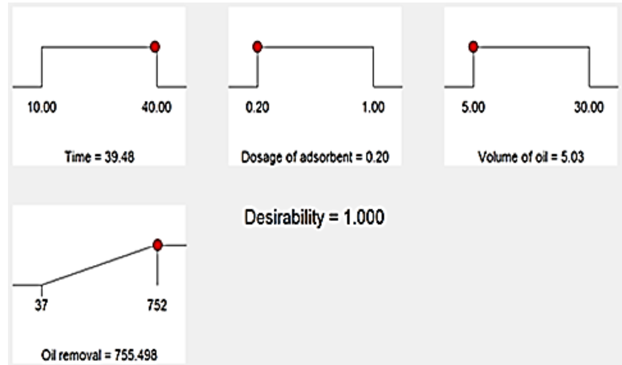

Fig. 3. Optimum conditions for maximum percentage for oil removal of adsorbent-based pineapple peel waste and used lubricating oil.

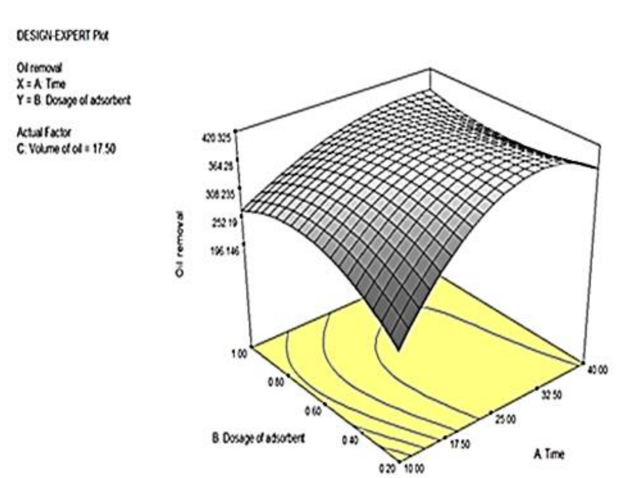

Fig. 4. Response surface for lubricant oil removal as a function of dosage, time and oil volume in cubic model.

Table 5: Model validation for oil adsorption.

Time of contact (minute), X1	Adsorbent dosage (g), X2	Volume of oil (mL), X3	Percentage of oil adsorption (%)	
			Predicted	Experiment
39.48	0.20	5.03	755.498	703.17

Based on the experiment conducted on the pineapple peel waste on the adsorption of oil, it can be concluded that the longer the contact time, the higher the percentage of oil removal. The adsorbent have enough time to adsorb the oil in 40 minutes compared to just 10 minutes of contact time.

The effect of adsorbent dosage varies according to the experiment. Majority of the experiment conducted shows that as the dosage decrease, the oil removal efficiency increase. This is mainly contributed by the size of packaging of the pineapple peel powder. All the dosage was placed in a same size sachet. Less dosage means more contact surface between the oil and the adsorbent. Higher dosage means less surface contact as it is packed inside the sachet for the optimum oil removal process to take place.

Volume of oil affects the experiment on the basis that higher volume of oil means higher oil removal efficiency. More oil can be adsorbed by adsorbent during the experiment.

4.0 CONCLUSION

In this study, pineapple peel waste was productively prepared by soda treatment method for oil adsorption for the cleanup and recovery of spilled oils. The oils can be speedily removed from water surface by affixing the pineapple peel waste in oil and water mixture, and the oil sorption capacity of the pineapple waste is in the range of 19.5% - 752%. Furthermore, it can be explained that the viscosity of oil affects the percentage of oil removal by adsorbent capacity. The viscosity of lubricant oil is 0.213Pa.s while cooking oil is 0.073Pa.s according to Li et al., (2012) [6].The used lubricant oil has a higher viscosity hence, can remove higher amount of oil. The pineapple peel waste is collected easily from water surface, and the absorbed oil can be kept in the pineapple peel waste assembly well in the form of semisolid after removing oil-loaded pineapple peel waste from water surface. This pineapple peel waste, which has the advantages of low cost, abundant, high sorption capacity, and fast sorption rate, may be a promising substitute for synthetic oil-absorbing fiber used for oil adsorption and for the removal of spilled oil.

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