Research Paper

Optimization of Acetone Concentration and Reflux Ratio for Enhanced Oil Extraction from Spent Bleaching Earth: A Response Surface Methodology Approach

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Abstract

Spent bleaching earth with an oil content exceeding 3% is classified as hazardous and toxic waste, requiring appropriate processing prior to environmental disposal. Extraction is one effective method for processing spent bleaching earth. This study focuses on the optimization of oil extraction from spent bleaching earth using acetone as a solvent, specifically analyzing the effects of solvent concentration and reflux ratio on oil recovery efficiency and evaluating the quality of recovered bleaching earth for potential reuse in vegetable oil refining processes. The extraction method employed was soxhlet extraction using acetone as the solvent. Five different acetone concentrations (50%, 60%, 70%, 80%, and 90%) were tested in combination with five reflux ratios (2, 3, 4, 5, and 6), creating a total of 25 experimental conditions. Response surface methodology (RSM) was utilized to optimize these parameters and identify the ideal conditions for maximum oil recovery. The experimental design and statistical analysis were conducted using Design Expert 13.0.5.0 software. The quality of recovered bleaching earth was assessed against Indonesian National Standards (SNI) for potential reuse applications. The optimization results indicated optimal conditions of 69.15% acetone concentration and a reflux ratio of 4, yielding a maximum oil recovery rate of 17.52%. Analysis of the recovered bleaching earth showed that while it met most SNI standards for bleaching earth quality parameters, the pH remained acidic (below neutral), indicating that alkaline pretreatment would be necessary before the material could be effectively reused in vegetable oil bleaching processes. The study demonstrates that acetone-based soxhlet extraction can effectively recover oil from spent bleaching earth while producing a secondary product suitable for reuse after appropriate pH adjustment.

Keywords

Acetone, Oil Extraction, Reflux Ratio, Response Surface Methodology, Spent Bleaching Earth

1. INTRODUCTION

Spent bleaching earth is derivated from bentonite clay after adsorpsion of impurities from crude oil during bleaching process (Maged et al., 2020). Spent bleaching earth is a major waste product generated during vegetable oil refining, particularly in palm oil processing. This waste contains 20-40% residual oil (Handoko et al., 2024; Placxedes et al., 2024) and is classified as hazardous toxic waste when oil content exceeds 3%, according to Indonesian Ministry of Environment and Forestry Regulation No. 6 of 2021. Spent bleaching earth in global production is reaching approximately 4.8 million tons in 2019 (Tetrisyanda and Wibawa, 2022), particularly from Indonesia and Malaysia's palm oil industries, effective waste management has become critical for both economic recovery and environmental protection such as contamination of groundwater and soil (Merikhy et al., 2019; Sabour and Shahi, 2018). Moreover, the economic implications of SBE management cannot be overlooked. The continuous demand for bleaching earth in the palm oil industry leads to increased production of spent bleaching earth, representing a significant economic loss if not managed properly (Handoko et al., 2024).

Current research has explored various oil recovery methods from SBE, including with heating or chemical treatment, with or without solven solution extraction such as n-hexane, petroleum ether, and methylene chloride, microwave-assisted extraction, reactivation processes (Plata et al., 2020). Microwave-assisted extraction have been explored to recover

residual oil from spent bleaching earth efficiently, extracted oil using this method is 10.43% (Dejkajorn et al., 2021), which can then be utilized in biodiesel production or as a lubricant (Naser et al., 2021). Reactivation processes have been investigated to allow the reuse of bleaching earth in subsequent bleaching cycles, thereby reducing waste generation (Latisya et al., 2024). Thermal reactivation of spent bleaching earth needed 108 min at high temperature 578°C to produce recovered bleaching earth (Bachmann et al., 2020). Acid reactivation of bleaching earth can also be carried out using sufuric acid and heat (Bayram et al., 2021; Darmawan et al., 2020). Solvent extraction is another promising technique for recovering oil from spent bleaching earth. Oladosu et al. (2017) highlighted the use of n-hexane and furnace activation as effective methods for oil recovery, while Manimaran et al. (2020) provided a comprehensive overview of various polar and nonpolar solvents that can be employed in this process, including petroleum ether, acetone, and methylene chloride (Saini et al., 2021). Among these, acetone has shown promising results, with studies reporting oil recovery rates of up to 25.01% compared to n-hexane (19.50%) and isopropanol (17.83%). However, most previous studies have focused on single-factor optimization or simple comparative analysis without comprehensive process optimization. While previous research has demonstrated the effectiveness of various solvents for oil extraction from spent bleaching earth, there is a significant gap in the systematic optimization of extraction parameters using advanced statistical methods. Most existing studies have employed traditional one-factor-at-a-time approaches, which fail to capture the complex interactions between process variables. Furthermore, limited attention has been given to the dual objective of maximizing oil recovery while simultaneously ensuring the quality of recovered bleaching earth for potential reuse. This study addresses these limitations by employing response surface methodology with a quartic model to optimize both acetone concentration and reflux ratio simultaneously, while comprehensively evaluating the recovered bleaching earth quality against Indonesian National Standards (Indonesian Nasional Standarization Agency, 2000).

2. EXPERIMENTAL SECTION

2.1 Chemical
The materials utilized in this research included pure technical acetone with a concentration of 99.99% as the extraction solvent, aquadest as the diluent for acetone, spent bleaching earth sourced from a local cooking oil manufacturing facility, and crude palm oil.

2.2 Instrumentation
The tools included a three neck boiling flask 500 mL (Duran), allihn condenser (Pyrex), soxhlet (Duran), thermometer, static and clamping, electric stove (Maspion), pot, pH-meter, filter paper, rope, stirrer motor, oven (Memmert), volumetric flask (Iwaki), sieve 200 mesh, measuring cylinder 100 ml (Herma), X-Ray Fluorescence (PANalytical Minipal 4), Spectrophotometer UV-Vis (Hitachi U-2900). The soxhlet extractor will be run as shown in Figure 1.

Figure 1 shown that the soxhlet extractor range includes a alihn condenser, extractor, three neck boiling flask, electric stove and, clamp, static, thermometer. Sample wrapped by filter paper and tied with rope.

2.3 Procedure
The methods to be used is extraction. Soxhlet extraction uses varation in acetone solvent concentration (50%; 60%; 70%; 80%; 90%) and reflux ratio (2; 3; 4; 5; 6) to determine the highest yield within lowest concentration of acetone solvent and fewer reflux ration in the extraction process. The procedure flowchart will be run as shown in Figure 2.

Based on Figure 2, The material preparation process consists of two main components: preparation of the spent bleaching earth and the preparation of the acetone solution. For spent bleaching earth preparation, 50 grams of spent bleaching earth were accurately weighed and then wrapped in filter paper. The 500 ml acetone solution was prepared by diluting acetone with distilled water using Equation 1 to achieve the desired concentrations of 50%, 60%, 70%, 80%, and 90%, corresponding to the independent variables used in the study. Based on Equation 1, V_1 is volume of acetone, M_1 is concentatrion of acetone, V_2 is volume of distillated water, and M_2 is concentration of distillated water.

$$V_1 \times M_1 = V_2 \times M_2 \tag{1}$$

The wrapped spent bleaching earth was placed in a soxhlet extractor, while the acetone solution was transferred to a three-neck flask. Extraction was conducted at a temperature of ±75°C until the specified reflux ratios of 2, 3, 4, 5, and 6 were achieved, corresponding to the independent variables. Upon completion of the extraction, the package containing the bleaching earth, referred to as recovered bleaching earth, was opened and subsequently placed in an oven at 100°C for 1 hour.

2.4 Analysis
Analysis of spent bleaching earth from which oil has been extracted is carried out in several stages such as analysis of recovered oil (yield), optimization using response surface methodology, and quality analysis of recovered bleaching earth. The evaluation parameters included yield, pH, oil bleaching efficiency, moisture content, grain size test and the chemical composition of the recovered bleaching earth.

2.4.1 Yield
The dried recovered bleaching earth was then weighed to calculate the oil yield using the appropriate formula. Based on Equation 2, yield is obtained by subtracting the weight of spent bleaching earth from the weight of recovered bleaching earth divided by the weight of spent bleaching earth.
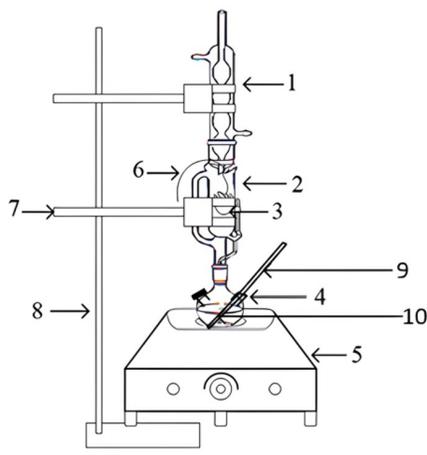
Explanations:

1. Allihn condensor
2. Extractor
3. Sample wrapped by filter paper
4. Three neck boiling flask
5. Electric stove
6. Rope
7. Clamp
8. Static
9. Thermometer
10. Pot

Figure 1. Soxhlet Extraction

$$\text{Yield (Y)} = \frac{w1 - w2}{w1} \times 100\% \qquad (2)$$

2.4.2 Optimization Using Response Surface Methodology

The yield obtained was analyzed using Response Surface Methodology (RSM) with the optimal split plot design, specifically employing a Type I optimal design and a quartic model, utilizing Design Expert 13.0.5.0 software.
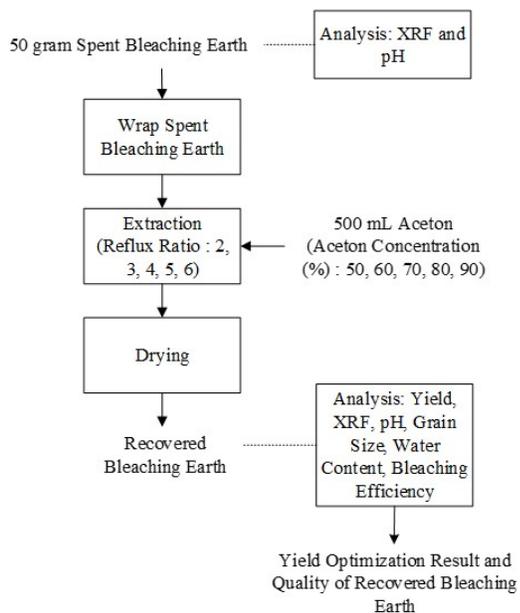

Figure 2. Flowchart of Optimization of Acetone Concentration and Reflux Ratio for Enhanced Oil Extraction From Spent Bleaching Earth Using a Response Surface Methodology Approach

2.4.3 Quality Assessment

The quality of the recovered bleaching earth was evaluated based on SNI-6363-2000 standards, which regulate the use of bentonite for bleaching vegetable oils. The tests were conducted both physically and chemically. Chemical testing, x-ray fluorescence (XRF) analysis was used to determine the composition of the recovered bleaching earth and ensure it complies with SNI standards. The chemical composition was compared against spent bleaching earth. Physical testing included water content test of the recovered bleaching earth was measured using an oven, pH test, grain size test, and bleaching efficiency. The pH of the recovered bleaching earth was tested by dissolving 10% of the earth in 100 mL of distilled water. The pH was then measured using a pH meter. The grain size distribution of the recovered bleaching earth was determined using a 200 mesh sieve. The weight of the earth retained in the sieve was recorded. The bleaching efficiency, a 25 gram sample of crude palm oil was bleached with 2.5% recovered bleaching earth at 105°C for 30 minutes. The oil was then filtered, and the color change before and after bleaching was observed. UV-Vis spectrophotometric analysis was conducted to measure the efficiency of color bleaching based on the wavelengths 470 nm of ultraviolet and visible light. The bleaching efficiency is calculated using Equation 3 below, where A is the oil color value before bleaching and B is oil color value after bleaching.

$$\eta = \frac{A - B}{A} \times 100\% \qquad (3)$$

3. RESULT AND DISCUSSION

3.1 Yield Analysis

The optimization of the extraction of spent bleaching earth (SBE) using acetone as a solvent through response surface methodology (RSM). The objective is to investigate the

Table 1. Observational Data and Measurements from Spent Bleaching Earth with Soxhletation Extraction Experiments

Solvent Concentration (%)	Reflux Ratio (cycle)	Yield/ Oil (mL)	Yield (%)
50	2	0.14	0.26
	3	2.35	4.24
	4	3.39	6.59
	5	3.90	7.23
	6	4.93	8.88
60	2	3.21	5.79
	3	5.39	9.71
	4	6.09	10.95
	5	5.26	9.47
	6	6.99	12.58
70	2	4.40	7.92
	3	8.03	14.41
	4	10.24	18.43
	5	10.40	18.72
	6	7.26	13.07
80	2	5.39	9.7
	3	4.80	8.63
	4	5.54	9.97
	5	3.39	6.09
	6	4.15	7.48
90	2	4.40	7.93
	3	3.29	5.92
	4	2.72	4.9
	5	1.64	2.95
	6	1.27	2.28

influence of acetone concentration and extraction reflux ratio on the obtained bleaching earth, and to determine the optimal influence of solvent concentration on the amount of extraction reflux using RSM. The spent bleaching earth was initially subjected to pH testing and weighing. Subsequently, Soxhlet extraction was performed using acetone as the solvent at specific concentrations for a duration corresponding to the experimental variables. The extracted oil from spent bleaching earth will be optimized using RSM. Recovery bleaching earth, was analyzed for its quality using X-ray fluorescence (XRF), UV-Vis spectrophotometry, and physical tests including pH, particle size, and moisture content. Several factors that is important as yield and solvent recovery is listed in Table 1.

Yield on Table 1 is the result of calculation using Equation 2. Based on Table 1, the extraction of oil from spent bleaching earth (SBE) is significantly influenced by various parameters, including reflux ratio and solvent concentration. The highest yield obtained is 18.72% with acetone concentration is 70 and reflux ratio is 5. According to Merikhy et al. (2019), extending the reflux ratio during extraction can lead

to an increase in oil yield, with optimal conditions allowing for recovery rates of up to 82.95% of the total oil content in SBE. This observation is corroborated by the data presented in their study, which indicates a positive correlation between reflux ratio and oil extraction volume. The longer the reflux ratio, the higher the volume of oil extracted, suggesting that time is a critical factor in maximizing yield. In addition to reflux ratio, the choice of solvent and its concentration plays a pivotal role in the extraction process. Merikhy et al. (2019) reported that using acetone as a solvent resulted in a higher oil recovery compared to lower yields obtained with other solvents. This highlights the importance of selecting an appropriate solvent concentration to optimize extraction results. The study indicates that the oil volume obtained from Soxhlet extraction using acetone was significantly higher than that obtained with other solvents, reinforcing the notion that solvent choice directly impacts extraction efficiency (Merikhy et al., 2019). While, the correlation between acetone concentration and oil volume, as reported by Carré et al. (2025) shows that the use of optimal acetone concentration can increase the extracted oil volume. The use of acetone yielded an oil recovery of 25.01%, while other solvents such as n-hexane produced lower yields (19.50%) and isopropanol (17.83%). This indicates that the selection of the appropriate solvent concentration significantly affects the extraction results. The results of the yield analysis are used to analyze yield optimization using ANOVA analysis.

3.2 ANOVA Analysis

Based on ANOVA (Analysis of Variance) that using Design-Expert 13 software, response surface methodology (RSM) was employed to analyze the data. The analysis revealed an F-value of 8.07, indicating that the model employed in this analysis is significant. However, there is a 0.11% probability that this f-value could arise from random fluctuations. The p-value, being less than 0.05, signifies that the model is statistically significant. Therefore, the ANOVA analysis provides a comprehensive overview of the influence of these variables on the extraction yield. In this context, variables A2 and A4 were identified as significant models. Conversely, a p-value greater than 0.1 indicates that the model is not significant. To enhance the accuracy of the optimization model, it is recommended to eliminate non-significant variables from the analysis. By taking this step, it is anticipated that the calculation model can be improved to provide more accurate and relevant results in the context of yield optimization. The following in Table 2 are the result of ANOVA calculation.

The statistical analysis of the extraction process base on Table 2, particularly through ANOVA using design-expert software, reveals significant insights into the relationship between the variables involved. It is show that the predicted R^2 value of 0.6650 aligns with the Adjusted R^2 value of 0.8048. The difference between the predicted R^2 and adjusted R^2 is less than 0.2, which, according to design-expert
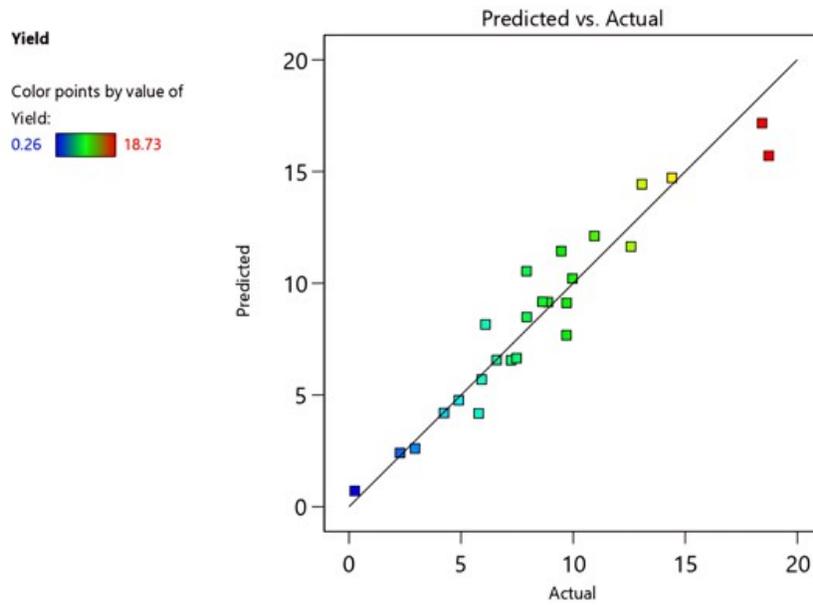
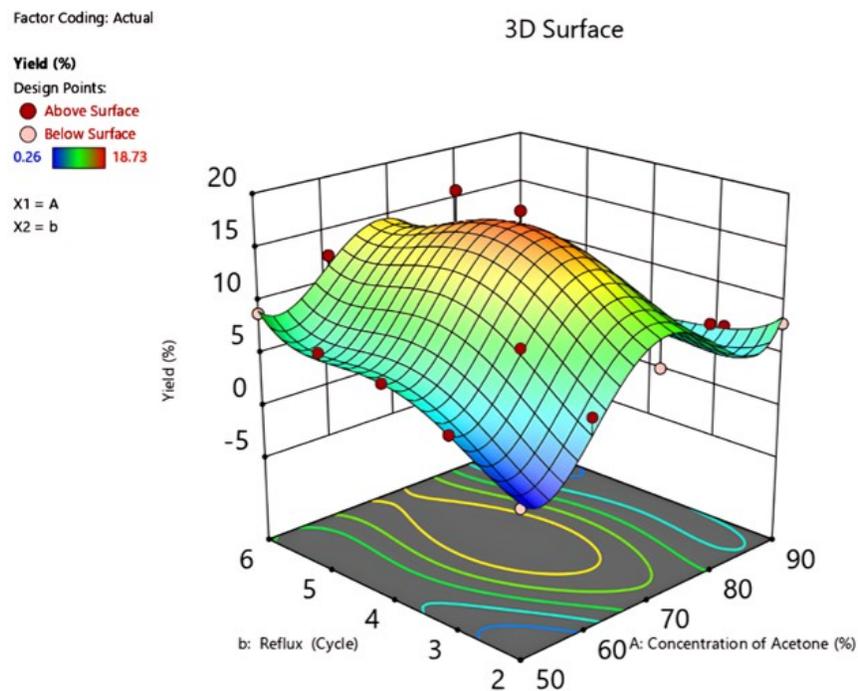**Figure 3.** Response Plot Comparison of Predicted and Actual Yield

Figure 4. Response Surface Relation of Acetone Concentration and Reflux Ratio on Yield

13.0.5.0, indicates that the quartic model can be used. However, if the difference exceeds 0.2, the model equation cannot be used as it suggests that the model should be revised to improve prediction accuracy and data fit. The C.V.% of 23.14 indicates a desirable comparison. The adeq precision value of 10.7176 signifies an adequate signal, indicating that this model can be used to navigate the design space for yield. An Adeq Precision value greater than or equal to 4 ($\geq$ 4) suggests that the model has sufficient signal for reliable predictions within the design space used. The coefficient of determination (R^2) of 0.9187, being close to 1, indicates that the model's predictions closely approximate the experimental results. The results of calculations using ANOVA can be used to analyze the surface response.

Table 2. Linear model of Spent Bleaching Earth Extraction Method using ANOVA Analysis

Equation Model	Model	ANOVA Analyst		
		R^2	Adjusted R^2	Predicted R^2
Coded	$Y = 17.17 - 2.24A + 0.6696B - 3.24AB - 28.17A^2 - 8.87B^2 - 1.35A^2B + 1.16AB^2 + 1.34A^3 + 1.28B^3 + 4.2A^2B^2 + 0.8187A^3B - 1.21AB^3 + 16.67A^4 + 4.19B^4$			
Actual	$Y = 2381.01049 - 139.57198(\text{Acetone Concentration}) - 130.71885(\text{Reflux}) + 3.36719(\text{Acetone Concentration} \times \text{Reflux}) + 3.05015(\text{Acetone Concentration})^2 + 26.46635(\text{Reflux})^2 - 0.33432(\text{Acetone Concentration}^2 \times \text{Reflux}) - 0.261843(\text{Acetone Concentration} \times \text{Reflux}^2) - 0.029218(\text{Acetone Concentration})^3 - 3.49708(\text{Reflux})^3 + 0.002624(\text{Acetone Concentration}^2 \times \text{Reflux}) + 0.000051(\text{Acetone Concentration}^3 \times \text{Reflux}) - 0.007592(\text{Acetone Concentration} \times \text{Jumlah Refluks}^3) + 0.000104(\text{Acetone Concentration})^4 + 0.261750(\text{Reflux})^4$	0.9187	0.8048	0.6650

3.3 Response Surface Methodology Analysis

Response surface methodology can optimize yield of recovered bleaching earth based on the results of observations and calculations using anova analysis. The actual yield from experimental data is compared with predicted yield from ANOVA calculation result formula. The following in Figure 3 shown response plot comparison of predicted and actual yield.

The graphical representation of the predicted versus actual yields illustrates the model's predictive accuracy. Points clustering near the diagonal line signify a strong correlation between predicted and observed yields, with a high R^2 value indicating a good fit of the model to the data (Merikhy et al., 2019). This reinforces the reliability of the model in predicting yield under various experimental conditions. Based on Figure 3, shown that the graph above, illustrating the relationship between predicted and actual yield, provides valuable insights into the accuracy of the model used in the analysis. In the graph, points that are increasingly blue indicate that the yield value is approaching the lower limit of 0.26%, while points that are increasingly red indicate that the yield value is approaching the upper limit of 18.73%. Points clustering near the diagonal line signify a strong agreement between predicted and observed yields. The more points that are close to the diagonal line, the better the model is at predicting yield values. The R^2 value, which quantifies the proportion of the variance in the dependent variable explained by the independent variables, further corroborates the model's accuracy. A higher R^2 value indicates a better fit of the model to the data. In this study, the high R^2 value, coupled with the observed pattern in the scatter plot, suggests that the model is capable of accurately predicting yield under various experimental conditions.

Optimization efforts aim to maximize oil yield while minimizing operational conditions, such as acetone concentration and reflux ratio. The study demonstrates how simultaneous changes in these two independent variables influence yield, with optimal conditions identified through experimental validation. This optimal point showed a minimal discrepancy between experimental and predicted yields, falling within an acceptable error margin (Merikhy et al., 2019). The response surface of acetone concentration and reflux ratio on yield is shown in Figure 4.

Based on Figure 4, experimental data points are marked in red, while contour lines represent constant yield values. This graph provides valuable insights into how these two independent variables jointly affect the extraction outcome. The color gradient on the graph corresponds to the yield level. Experimental data points are marked in red, and contour lines represent constant yield values. Red areas on the graph indicate regions with higher yields, approaching the upper limit of 18.73%. Conversely, blue areas indicate regions with lower yields, approaching the lower limit of 0.26%. Thus, the closer to red, the more optimal the conditions for achieving a high yield. The graph also illustrates the interaction between acetone concentration and reflux

ratio. Increasing the reflux ratio up to 6 cycles shows a significant increase in yield. However, further increases do not yield significant changes. This indicates a saturation point or optimal point where additional reflux no longer improves extraction efficiency. Based on the graphical analysis, the optimal point was identified at an acetone concentration of 70% and a reflux ratio of 4 cycles, resulting in a yield of 18.43%. This suggests that a specific combination of these two variables can maximize extraction results. According to Design-Expert 13.0.5.0, the predicted optimal values are an acetone concentration of 69.153% and a reflux time of 4 cycles, resulting in a yield of 17.228% with a selected desirability of 0.919. The interaction between these two variables indicates that process optimization requires careful consideration of the combination of both factor. The response contour plot optimization of acetone concentration and reflux ratio on yield is shown in Figure 5.

Table 3. Comparison of Optimization of Aceton Concentration and Reflux Ratio on Yield Predicted and Experimental Data

Variable	Acetone Concentration (%)	Reflux Ratio (cycles)	Yield (%)
Predicted	69.152	4	17.228
Experienced	69.152	4	17.521

This contour plot depicts the region where the combination of reflux ratio and acetone concentration yields the optimal desirability shown in Figure 5. Desirability is a combined value of reflux ratio and acetone concentration that is sought to be optimized. Regions with a more reddish hue indicate more desirable combinations, while regions closer to blue indicate less desirable combinations. The red dots on the graph represent experimental data points. This graph specifically demonstrates the relationship between reflux ratio, acetone concentration, and yield. The contour lines on the graph represent constant yield values. Regions with higher contour values indicate higher yields. The red dots represent experimental data that corresponds to the predicted yield value at that point. Therefore, an experiment was conducted to confirm the actual optimal point. The experiment was repeated once under operating conditions of 70% acetone concentration and 4 reflux cycles. The following in Table 3 is a comparison of the confirmation of optimization results.

From Table 3, A discrepancy of 0.293% was observed between the experimental and predicted yields. The calculated error of 1.67% (or 0.0167) falls within the acceptable error margin, as indicated by a significance level of $P<0.05$. This finding supports the validity of the model and its ability to accurately predict the optimal conditions. The optimal conditions identified were an acetone concentration of 69.152%

and a reflux ratio of 4 cycles, yielding 17.521%.

3.4 Characteristics Analysis of Recovered Bleaching Earth

Recovered bleaching earth from optimizing spent extraction bleaching earth can be considered again for reuse as a bleaching agent in the bleaching process in the cooking oil industry. This can only happen if the pressed bleaching earth produced complies with bentonite quality standards as bleaching earth. The following in Table 4 is a comparison recovered bleaching earth with Indonesian quality standar (SNI) of bentonite as bleaching earth.

Table 4. Comparison Recovery Bleaching Earth with Indonesia Quality Standard (SNI) of Bentonite as Bleaching Earth.

Standard	Recovered Bleaching Earth	Standard Bleaching Earth
Chemical		
SiO_2 Contain	61.2%	<70%
Al_2O_3 Contain	12%	<15%
Physical		
pH	3.45-3.49	6.5-8.5
Moisture Contain	4.76%	<15%
Grain Size on 200 Mesh	0.02%	<2.5%
Color bleaching efficiency	75.8082%	>40%

The characteristics of bleaching earth were evaluated according to SNI:13-6363-2000 standards for bentonite as a bleaching agent, encompassing both chemical and physical properties. Based on Table 4, chemical analysis revealed that the recovered bleaching earth met the standard specifications, containing 61.2% silicon dioxide and 12% aluminum oxide, which fall within the maximum allowable limits of 70% and 15%, respectively. Commercial bentonite as a bleaching agent contains 60.88% silicon dioxide and 0.78% aluminum dioxide (Alamri et al., 2021). According to Yuan et al. (2020), the silicon dioxide content in bleaching earth is 70.87% and the alumunium dioxide is 11.83%. The silicon oxide content in spent bleaching earth (SBE) exhibits excellent adsorption properties while maintaining the physical stability of the SBE structure and ensuring thermal resistance at elevated temperatures (Yao et al., 2020). From a physical perspective, the recovered bleaching earth demonstrated compliance with established standards, exhibiting a moisture content of 4.76% (below the 15% maximum threshold), particle retention at 200 mesh of 0.02% (within the 2.5% maximum limit), and an oil bleaching efficiency of 75.8082% (exceeding the minimum requirement of 40%). Moisture content of bleaching earth used for oil bleaching
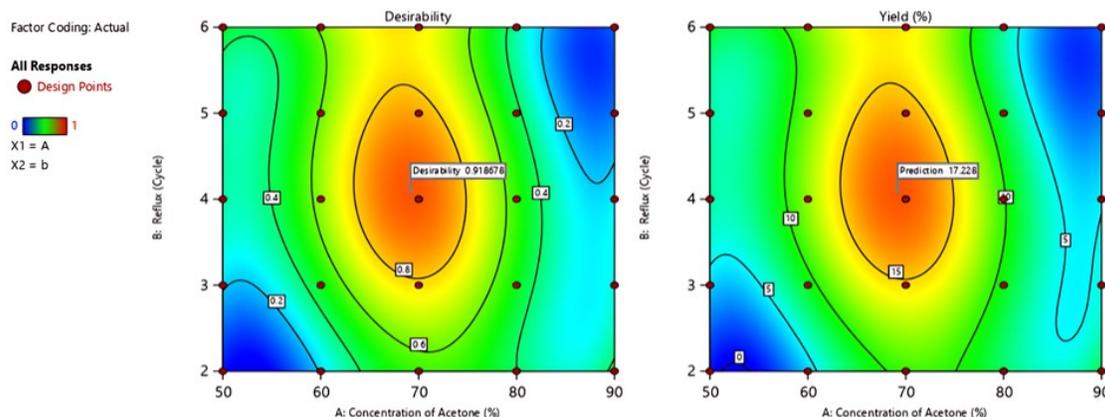
Figure 5. Response Contour Plot Optimization of Acetone Concentration and Reflux Ratio on Yield

is 12% (Soetaredjo et al., 2021). The high oil bleaching efficiency indicates the potential for reusing the recovered bleaching earth in subsequent bleaching processes. However, a deviation was observed in the pH characteristics of the recovered bleaching earth, which exhibited acidic properties instead of the required neutral to slightly basic range. This acidic condition can be attributed to the presence of sulfur trioxide, which reacts with water present in the RBE to form free sulfuric acid (Yao et al., 2020), resulting in the observed acidic pH range.

Table 5. Comparison of the Extraction Results of Spent Bleaching Earth using Several Solvents

Solvent	Yield (%)	Bleaching Efficiencies (%)
Methyethylketone	72	73
Acetone	67	65
Potroleum ether	60	51
Hexane	42	27

3.5 Solvent Comparison

The extraction of spent bleaching earth using a solvent extraction method depending on the solvent used. The following in Table 5 is a comparison of the extraction results of spent bleaching earth using several solvents.

Based on Table 5, In the study conducted by Aldebasir et al. (2023), the comparison of solvent extraction results for spent bleaching clay revealed distinct differences in performance among the solvents tested, namely methylethylketone (MEK), acetone, petroleum ether, and hexane. While MEK achieved the highest percentage of oil extracted (POE) at 72%, acetone followed closely with 67%, demonstrating its effectiveness as a solvent. However, acetone exhibited notable advantages over the other solvents, particularly in terms of the quality of the reactivated clay post-calcination. The

bleaching efficiency (PB) of clay decoiled by acetone reached 94% after calcination at 500°C for 120 minutes, surpassing MEK (91%) and significantly outperforming petroleum ether (86.3%) and hexane (90%). This superior performance can be attributed to acetone's ability to efficiently remove oil and impurities without compromising the clay's structural integrity, as evidenced by the high surface area of the reactivated clay (185.0 m^2/g compared to MEK's 182.3 m^2/g). Additionally, acetone's moderate extraction yield balanced oil recovery with minimal degradation of the recovered oil quality, making it a more versatile and practical choice for industrial applications. These findings highlight acetone as a highly effective solvent for both oil extraction and clay regeneration, offering a compelling combination of efficiency, reactivation potential, and environmental benefits.

4. CONCLUSIONS

This study successfully to demonstrating the effectiveness of response surface methodology in optimizing aseton concentration and reflux ratio for enhancing oil extraction spent bleaching earth. The results indicated that the concentration of acetone and the reflux ratio significantly influenced oil yield. The optimal conditions identified an acetone concentration of 69.15% and a reflux ratio of 4 resulted in a maximum oil recovery of 17.52%. The quality of the recovered bleaching earth met Indonesian national standards for for repurposing SBE into a valuable resource. However, the acidic pH of the recovered bleaching earth necessitates further pretreatment before reuse such as neutralization.

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