

Processing of Rice Husk into Bleaching Earth Using the Precipitation Method for Adsorption of Colorants in Palm Oil

Fidela Lathifa Haryati^{1✉}, Puspa Prima Andini², Nurul Widji Triana³, Susilowati⁴, Suprihatin⁵

^{1, 2, 3, 4, 5} Department of Chemical Engineering, Faculty of Engineering and Science, Universitas Pembangunan Nasional “Veteran” Jawa Timur, Indonesia

✉ Corresponding Author : Fidela Lathifa Haryati (e-mail: fidelalathifaharyati@gmail.com)

Article Information	ABSTRACT
Article History Received : September 07, 2025 Revised : October 12, 2025 Published : October 20, 2025	Rice husk waste from rice milling in Indonesia contains high silica, making it a promising raw material for adsorbent synthesis. This research contributes to sustainable waste utilization and supports green technology in palm oil refining, providing both environmental and industrial significance. This study focuses on producing Bleaching Earth from rice husk using the precipitation method and applying it to adsorb colorants in used cooking oil. Rice husk ash (RHA) was reacted with sodium hydroxide (NaOH) to form sodium silicate, which was then precipitated using sodium aluminate (NaAlO₂) and hydrochloric acid (HCl) to obtain silica gel. The process variables were the volume of NaAlO₂ solution (15–35 mL) and stirring time (10–50 minutes). The synthesized Bleaching Earth was analyzed for moisture content, pH, chemical composition (XRF), and surface properties (BET). The best Bleaching Earth met the Indonesian National Standard (SNI 136336-2000), with a moisture content of 2.48–6.01%, neutral pH (~7), and mesoporous structure with pore diameters of 6.49–13.87 nm. The optimal adsorption performance occurred at a pore diameter of 11–12 nm, achieved using 25 mL NaAlO₂ with 50 minutes of stirring or 35 mL NaAlO₂ with 40 minutes of stirring. Application of this BE effectively reduced the color intensity of used cooking oil, producing lighter and clearer oil, confirming rice husk's potential as an eco-friendly, low-cost source for Bleaching Earth production.
Keywords: <i>Adsorption Of Used Palm Oil; Bleaching Earth (BE); Precipitation Method; Rice Husk Ash (RHA); Sodium Silicate.</i>	

INTRODUCTION

Indonesia, as one of Southeast Asia's largest rice producers, generates a substantial amount of rice husk waste from its milling processes. In 2022, the production of milled dry grain reached 53.98 million tons, of which 20–30% was rice husk, equivalent to approximately 10.73–16.09 million tons of waste (Rochdiani et al., 2022). Rice husk is rich in silica (SiO₂), containing about 80–95% silica in its ash form, making it a promising alternative raw material for silica-based industrial applications such as adsorbent synthesis (Kordi et al., 2024). Improper management of this agricultural residue not only contributes to environmental pollution but also represents a missed opportunity to convert waste into valuable materials.

Bleaching Earth (BE) plays an essential role in the refining of vegetable oils, particularly palm oil, where it acts as an adsorbent for pigments such as β -carotene and chlorophyll, as well

as for impurities including phospholipids, metals, and oxidation products (Olein & Veronika, 2023). Commercial BE is typically derived from bentonite clay through acid activation. However, dependence on bentonite poses economic and sustainability challenges, especially when agricultural by-products like rice husk can serve as abundant and low-cost alternative sources of silica. Previous studies have reported the potential of rice husk ash (RHA) as a precursor for silica-based adsorbents. Hadi and Sudiarta (2021) demonstrated that silica gel derived from RHA through precipitation exhibits a high surface area and showed that controlled acid concentration during precipitation improves porosity. Ulandari et al. (2024) and Ramdhani et al. (2018) emphasized that sodium aluminate addition and stirring time influence pore structure, while Mading (2025) highlighted that adsorbent mass and surface area strongly affect pigment adsorption efficiency. These findings confirm the feasibility of RHA as a raw material for Bleaching Earth production.

Despite these advancements, studies on optimizing the synthesis parameters of RHA-based Bleaching Earth to meet national standards and achieve optimal pore structures for palm oil bleaching remain limited. Most previous studies have not comprehensively analyzed how variations in sodium aluminate concentration and stirring duration affect key physicochemical characteristics such as surface area, pore diameter, and adsorption performance. As shown in Table 1, the main characteristics of *Bleaching Earth* that comply with the Indonesian National Standard (SNI 136336-2000) include water content, pH suspension, specific gravity, and particle size.

Table 1. Properties of Bleaching Earth

Test Component	Unit	<i>Bleaching Earth</i>
Water Content (bk)	(%)	Maks 15
pH Suspense (pH)		6,5 – 8,5
Specific Gravity	(gr/ml)	2,0 – 2,7
Particle Size	mesh	100

(source : BSN 2000)

Therefore, this research aims to synthesize *Bleaching Earth* from rice husk ash using the precipitation method to produce a material that meets the national standard and to determine the optimal pore diameter for effective colorant adsorption in used cooking oil. This study is expected to contribute to sustainable waste management and provide a low-cost, eco-friendly adsorbent for the palm oil industry.

RESEARCH METHODS

Time and Location. This experimental research was conducted over two months at the Chemical Engineering Research Laboratory, Universitas Pembangunan Nasional "Veteran" Jawa Timur.

Materials. The main raw material was 500 grams of rice husk obtained from a rice mill in Gresik, East Java. Other chemicals used were NaOH 3 N, HCl 5 N, $\text{Al}(\text{OH})_3$, and distilled water.

Synthesis of Bleaching Earth. The rice husk was washed, sun-dried for one day, and then furnace-fired at 700°C for 240 minutes to produce RHA. The RHA was ground and sieved through a 100-mesh sieve. Fifty (50) grams of RHA were mixed with NaOH 3 N. This mixture was heated at 90°C and stirred at 300 rpm for 60 minutes to form a sodium silicate solution. Simultaneously, a sodium aluminate solution was prepared by dissolving 35 grams of $\text{Al}(\text{OH})_3$ in a solution of NaOH, heated at 90°C until homogeneous. The sodium silicate and sodium aluminate solutions were mixed according to the research variables: sodium aluminate volume (15, 20, 25, 30, 35 mL) and stirring time (10, 20, 30, 40, 50 minutes) at 90°C and 300 rpm. HCl 5 N was then added to the mixture to precipitate the silica gel, adjusting the pH to 7. The resulting precipitate was filtered, washed with distilled water, and dried in an oven at 120°C for 120 minutes.

Application to Palm Oil. 5 grams of the synthesized Bleaching Earth were added to 50 mL of used cooking oil. The mixture was heated to 95°C and stirred for 45 minutes. The oil was then filtered to separate the spent Bleaching Earth, and the clarity of the filtrate was observed.

Analysis. The synthesized Bleaching Earth was characterized for its moisture content, pH, chemical composition using X-Ray Fluorescence (XRF), and surface properties (surface area, pore volume, pore diameter) using the Brunauer-Emmet-Teller (BET) method.

RESULTS AND DISCUSSION

Characteristics of Raw Material (Rice Husk Ash)

Moisture content in Bleaching Earth can be analyzed using water content calculations to determine product humidity levels. Low moisture improves structural stability and prevents particle agglomeration, resulting in a larger active surface area. This enhances the adsorption efficiency of color pigments in oils.

$$\text{Moisture Content} = \frac{(w_1 - w_2)}{(w_2)} \times 100\%$$

$$\text{Moisture Content} = \frac{(500 \text{ gram} - 14,0453 \text{ gram})}{(14,0453 \text{ gram})} \times 100\% = 34,60\%$$

The initial characterization of the raw material, Rice Husk Ash (RHA), is crucial as its properties directly influence the quality of the synthesized Bleaching Earth. The moisture content of the raw rice husk was calculated to be 34.60%, which is within the typical range of 30–35% for fresh rice husk (Yan et al., 2022). A high moisture content can lead to energy inefficiency during the furnace process, as excess heat is used to evaporate water instead of decomposing organic compounds like cellulose and lignin into silica, potentially affecting the porosity of the resulting ash (Dahlan & Hariyanto, 2022).

X-Ray Fluorescence (XRF) analysis was conducted to determine the chemical composition of the RHA used. The results, compared to literature values (Prameswara et al., 2023), are presented in Table 2.

Table 2. Comparison of Rice Husk Ash (RHA) Composition Based on Literature and XRF Test Results

Chemical Compound	Composition Based on Literature (%)	Composition Based on Test Results (%)
Si	88,06	77,4
K	6,77	10,4
Ca	1,11	9,48
Fe	2,17	1,68
Mn	0,434	0,48

Source: (Prameswara et al., 2023 and State University of Malang Laboratory, 2025)

Based on the results in Table 2, significant changes were observed in the chemical composition of rice husk ash compared to literature values. The main components is obtained in this study were silicon (Si) 77.4%, potassium (K) 10.4%, calcium (Ca) 9.48%, iron (Fe) 1.68%, and manganese (Mn) 0.48%. The Si content (77.4%) was slightly lower than the reported literature value of 88.06% (Prameswara et al., 2023). This reduction is attributed to differences in combustion conditions and the origin of rice husk used. Despite being lower, the silica content remained sufficiently high to qualify as a raw material for Bleaching Earth. Silica is the dominant component that determines the pore structure and adsorption capacity of Bleaching Earth. A high silica content enhances the specific surface area and pore density, thereby improving adsorption

efficiency for colorants and impurities (Prameswara et al., 2023). The K content increased significantly to 10.4% compared to 6.77% in literature. This increase may result from the accumulation of potassium that did not fully oxidize during combustion or from variations in mineral composition of the rice husk (Prameswara et al., 2023). Similarly, the Ca content (9.48%) was much higher than the reported 1.11%. Elevated Ca levels could originate from soil nutrients where the rice plants were cultivated, or from insufficient washing during sample preparation. Calcium, as a minor metal oxide, can influence the surface interactions of Bleaching Earth with oil colorants and contaminants (Prameswara et al., 2023). The Fe content in this study (1.68%) was slightly lower than the literature value of 2.17%, while Mn (0.48%) was slightly higher than the literature reference of 0.434%. Both Fe and Mn generally act as impurities; however, their relatively low concentrations are unlikely to significantly affect the adsorptive performance of the Bleaching Earth (Kumalasari, 2024).

Moisture Content and pH of Synthesized Bleaching Earth

The analysis of moisture content in Bleaching Earth aims to determine the percentage of residual water in the final product, as moisture influences adsorption capacity, pore stability, and overall efficiency of the adsorbent.

Table 3. Moisture Content of Bleaching Earth

Volume of NaAlO ₂ (mL)	Moisture Content (%)				
	10 min	20 min	30 min	40 min	50 min
15	3,05	3,95	2,75	4,56	3,98
20	2,69	5,14	3,95	5,60	3,74
25	2,29	7,23	3,39	10,60	3,83
30	1,46	3,25	2,68	4,96	4,30
35	2,91	3,36	2,90	4,31	5,33
Average	2,48	4,58	3,13	6,01	4,24

Based on the results in Table 3, the moisture content of the synthesized Bleaching Earth ranged from 1.46% to 10.60%, with an average of 2.48–6.01%. According to the Indonesian National Standard (SNI 136336-2000), the maximum allowable moisture content for Bleaching Earth is 15%. Thus, all samples produced in this study met the quality requirement. Excessive moisture can block active pores and reduce adsorption efficiency by limiting the diffusion of colorants and impurities. Conversely, very low moisture content may indicate pore structure damage due to excessive drying, which decreases adsorption capacity (Silva, 2025). The variation in sodium aluminate volume and stirring time influenced the moisture level through changes in pore structure and particle aggregation. Kurniawati et al. (2019) reported that proper drying is essential to maintain pore stability in silica-based adsorbents, ensuring optimal adsorption. Similarly, Soetaredjo et al. (2021) confirmed that Bleaching Earth with moisture content below the SNI limit still demonstrates good adsorption performance.

The pH test of Bleaching Earth was done to make sure the pH stayed at 7, which is neutral after adding HCl. A stable and neutral pH is important to avoid oil damage and to keep the adsorption of colorants effective. Neutral pH also helps maintain the pore structure of Bleaching Earth so that its adsorption capacity remains good.

Table 4. pH Test Data with HCl Addition

Volume of NaAlO ₂ (mL)	Volume of HCl				
	10 min	20 min	30 min	40 min	50 min
15	2,5	3,75	4,5	5	5,25
20	3,75	4,25	4,75	5,25	5,75
25	4,25	4,75	5	5,75	6,25
30	4,75	5	5,25	6,25	7,5
35	5	5,25	5,75	6,75	8,25
Average	4,05	4,60	5,05	5,80	6,60

Based on Table 4, the Bleaching Earth obtained in the experiment initially showed alkaline properties, so HCl was added to adjust the pH to a neutral value (pH = 7). The amount of HCl required increased with larger solution volumes and longer stirring times because more hydroxide ions were released into the solution. The addition of HCl also promoted the release of silicate ions (Si(OH)₄) from the aluminosilicate matrix. At low pH, these silicate ions undergo condensation and polymerization to form Si–O–Si bonds, producing a three-dimensional silica gel network (Tsaousi et al., 2023). This gel formation reduces silica solubility and can interfere with the filtration process. A neutral condition is therefore considered optimal, as it prevents excessive silica gel formation at very low pH and avoids saponification reactions at high pH, ensuring maximum adsorption performance and stable oil quality (Silva et al., 2025).

Yield of Bleaching Earth

Yield is calculated to determine the percentage of solid products obtained from the precipitation process relative to the initial mass of raw materials. The yield value reflects the extent to which the chemical reaction reaches equilibrium. It also serves as an indicator of process stability and the efficiency of chemical utilization during the production of Bleaching Earth. A higher yield indicates that the precipitation process is more effective in producing a material with greater surface area and pore volume, thereby enhancing adsorption capacity. Variations in sodium aluminate volume and stirring time play a crucial role in pore structure formation and particle homogeneity, which in turn influence the quality and performance of Bleaching Earth.

Table 5. Yield Calculation Results of Bleaching Earth

Volume of NaAlO ₂ (mL)	Yield (%)				
	10 Min	20 Min	30 Min	40 Min	50 Min
15	42,19	57,23	59,26	66,41	68,25
20	53,42	60,38	62,66	68,29	69,52
25	57,34	61,91	65,71	71,27	72,72
30	57,91	62,91	66,41	71,98	73,69
35	59,20	65,14	66,54	78,32	84,12

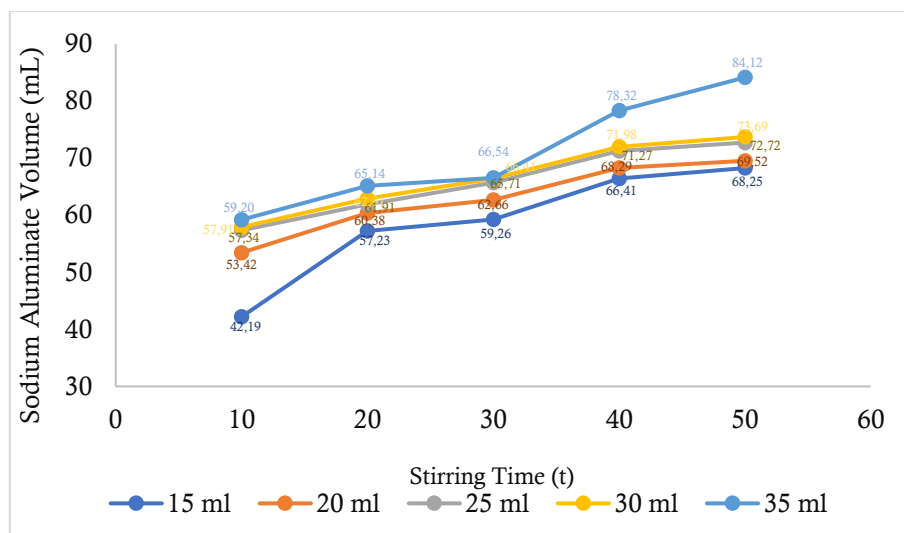


Figure 1. The Relationship Between Stirring Time and Sodium Aluminate Volume on Bleaching Earth Yield

Based on Table 5 and Figure 1, the yield of Bleaching Earth increased with higher sodium aluminate volume and longer stirring time. This shows a strong relationship between synthesis parameters and the formation of surface area and active pores. A higher yield indicates more solid precipitate, leading to greater active surface area and adsorption capacity. This result supports the findings of Mading (2025) that larger adsorbent mass provides more active sites, while Olein and Veronika (2023) reported that Bleaching Earth with a wider surface area produces clearer oil. Similar observations were also made by Ulandari et al. (2024) and Ramdhani et al. (2018), who showed that sodium aluminate addition and extended stirring promote pore development and structural homogeneity. The highest yield (84.12%) was obtained at 35 mL NaAlO_2 with 50 minutes stirring, while the lowest (42.19%) occurred at 15 mL NaAlO_2 with 10 minutes. High yield conditions favored precipitation and solid mass growth, whereas low yield was caused by insufficient reactant volume and short mixing time, resulting in incomplete reactions. Other factors also influenced the yield. At moderate calcination temperatures (600–800°C), water and volatiles were effectively removed, enhancing pore development without major mass loss. In contrast, excessive temperatures caused decomposition and evaporation of components, reducing yield (Silva et al., 2025). In addition, silica gel formation under acidic conditions near the isoelectric point ($\sim\text{pH } 2$) often reduced mass recovery. The gel tended to agglomerate into sticky, porous material that adhered to filter paper instead of settling as solid particles, thus lowering the measured yield. This agrees with Tsousi et al. (2023), who noted that silica gel formed at low pH can hinder sedimentation and decrease filtration efficiency.

Chemical Composition of Bleaching Earth (XRF Analysis)

Analysis of the chemical composition of the Bleaching Earth was conducted using the X-Ray Fluorescence (XRF) method to obtain accurate compositional results. The XRF method allows for the identification of elements in both oxide and elemental metal forms. The results of the chemical composition testing were then compared to standard data from the literature. This comparison aims to evaluate the consistency of the Bleaching Earth's quality and its conformity with expected standards. A comparison between the XRF analysis results of the Bleaching Earth composition and the literature standard is presented in Table 5.

Table 6. Comparison of Bleaching Earth Composition

Chemical Compound	Composition Based on Literature (%)	Composition Based on Test Results (%)
SiO ₂	51,1	43,1
Al ₂ O ₃	17,25	51,1
Fe ₂ O ₃	8,97	0,39
CaO	1,55	2,48
K ₂ O	1	1,1

(Source: Eleraky, 2025 and State University of Malang Laboratory, 2025)

Based on the data in Table 6, taken from the sample with a sodium aluminate volume of 35 mL and a stirring time of 40 minutes. the tested Al₂O₃ content was 51.1%, significantly higher than the literature standard of 17,25%. This significant increase is primarily due to the addition of sodium aluminate (NaAlO₂) during the synthesis stage. The addition of Al₂O₃ aims to increase the number of surface active sites and improve pore stability. Al₂O₃ itself is an amphoteric oxide that enhances surface acidity, thereby significantly increasing the adsorption capacity for colorants in oil (Salawudeen, 2025). This increase in Al₂O₃ is inversely proportional to the decrease in SiO₂, where the test results showed only 43.1%, lower than the literature value of 51.1%. SiO₂ plays a role in maintaining the basic characteristics of Bleaching Earth as a mesoporous adsorbent with a large surface area (Soylu, 2025). This difference can be attributed to the increased Al₂O₃ content, which reduces the relative proportion of SiO₂, and because during the acid activation and precipitation process, some silica dissolved in the acidic solution, reducing its effective content. Although lower, the SiO₂ content remains sufficiently high to maintain the material's mesoporous properties. The tested Fe₂O₃ content was only 0.39%, far below the literature value of 8,97%. This drastic reduction demonstrates the effectiveness of the acid activation stage in dissolving iron oxides.

This result is consistent with the research by Prameswara et al. (2025), which reported that acid activation significantly reduces Fe₂O₃, thereby preventing oil re-coloration due to Fe ion transfer during the bleaching process. This means that a low Fe₂O₃ content is an important advantage in improving product quality. The tested CaO content increased to 2.48%, much higher than the literature value of 1,55%. This increase likely originates from natural minerals in the rice husk or from additional reagents used. CaO can act as a weak base promoter, supporting pore structure formation and enhancing material stability. However, excess CaO may interfere with adsorption if it reacts with the acid activator. This relatively high CaO content must be considered when interpreting adsorbent performance (Placxedes, 2023). The K₂O content also increased from 1% to 1.1%. This increase is likely due to natural minerals from the rice husk that were not entirely removed during the calcination process. Nevertheless, K₂O content in this range does not reduce adsorption performance and may even help improve the material's thermal stability (Eyankware, 2021).

BET Analysis Results (Brunauer–Emmet–Teller)

BET testing was used to evaluate the adsorbent's total and single-point surface area. For Bleaching Earth, surface area is determined by the pore distribution number per unit area, whereas the specific surface area represents the surface available per unit weight of the material. The test results are presented in Table 7.

Table 7. BET Analysis Results (Brunauer–Emmet–Teller)

Volume of Sodium Aluminate (mL)	Stirring Time (min)	S_{BET} (m ² /gr)	Single Point Surface Area (m ² /gr)	Pore Diameter (nm)
25	50	28,362	25,11	11,26
30	40	38,739	32,89	13,87
30	50	39,938	35,62	6,67
35	40	59,837	50,43	11,99
35	50	66,367	54.20	6,49

(Source: Laboratory of Diponegoro University, 2025)

Based on the data in Table 6., it was found that variations in sodium aluminate volume and stirring time significantly affect the Specific Surface Area (S_{BET}), single-point surface area, and average pore diameter of the resulting Bleaching Earth. The BET analysis shows that the pore diameter of Bleaching Earth ranges from 6.49 to 13.87 nm, all of which fall into the mesopore category according to the IUPAC classification of 2–14 nm (Deutschland, 2015). The largest pore diameter (13.87 nm) was obtained with 30 mL sodium aluminate and 40 minutes of stirring. Wider pores support the diffusion of large molecules but tend to reduce pore tightness, resulting in a relatively lower specific surface area (Hanipa et al., 2017). Conversely, the smallest pore diameter (6.49 nm) was achieved with 35 mL and 50 minutes of stirring. Smaller pores can increase surface area but may limit the diffusion of large impurity molecules (Ramdhani et al., 2018). Intermediate conditions, such as 25 mL with 50 minutes of stirring (11.26 nm) and 35 mL with 40 minutes of stirring (11.99 nm), produced pore sizes within the 11–12 nm range. This size offers a balance between a sufficiently large surface area and good adsorbate diffusion capability (Ulandari et al., 2024). The optimal pore diameter range is 11–12 nm, as it effectively supports the performance of Bleaching Earth in the cooking oil bleaching process (Mading, 2025). The average pore diameters of all samples are within the mesopore range (6.49–13.87 nm), consistent with the standard pore size for Bleaching Earth of 2–14 nm (Deutschland, 2015).

Application of Bleaching Earth in Palm Oil

The application of Bleaching Earth in Palm oil aims to reduce pigments, impurities, and oxidizing compounds that affect the oil's color, clarity, and quality. This bleaching process utilizes the adsorptive properties of Bleaching Earth to remove pigments such as β -carotene and chlorophyll, which give the oil its yellow color. The results of this application are shown in Figure 2.

**Figure 2.** Application of Bleaching Earth in Cooking Oil

Based on the results in Figure 2, there is a significant change in the color of the cooking oil before and after the bleaching process using Bleaching Earth. Before treatment, the oil had a dark yellow color due to high levels of pigments like β -carotene and chlorophyll (Olein and Veronika,

2023). After the 45-minute adsorption process at 95°C, the oil became a lighter, clearer yellow, indicating successful pigment removal by the adsorbent (Silva et al., 2025). This color change indicates a reduction in impurities that affect oil quality (Mading, 2025). These findings align with the research of Soetaredjo et al. (2021), which states that silica-based Bleaching Earth is highly effective in reducing the color intensity of cooking oil. The bleaching results in this study were influenced by several factors, including the surface area and pore size of the Bleaching Earth. Optimal conditions from BET analysis were achieved with 25 mL of sodium aluminate and 50 minutes of stirring (pore size 11.26 nm) and 35 mL with 40 minutes of stirring (pore size 11.99 nm), placing the pore size in the ideal 11–12 nm range (Deutschland, 2015). This optimal surface area and pore size allow for greater interaction between oil pigments and the adsorbent's active sites (Mading, 2025). Furthermore, a low moisture content (1.46–10.60%) prevents pores from being blocked by moisture, thereby increasing adsorption capacity (Kumiawati et al., 2019). A neutral pH (pH = 7) also supports oil stability during bleaching, preventing side reactions such as hydrolysis or saponification (Silva et al., 2025).

The bleached oil showed improved clarity and reduced color intensity (Olein & Veronika, 2023). The process is also estimated to reduce oxidative compounds and other impurities that can affect the shelf life of the oil (Soetaredjo et al., 2021). According to Plaxedes et al. (2023), the reduction in pigments is directly proportional to the decrease in pro-oxidative activity in the oil, thereby slowing down rancidity. The use of rice husk-based Bleaching Earth is not only effective in bleaching but also has the potential to improve the oil's oxidative stability (Soylu, 2025). The significant color change from dark yellow to a much lighter shade is consistent with the research of Heryani (2019), which reported that on an industrial scale, bleached palm oil achieved an Optimum Large Pore Diameter with a color value of 19R – 21R, still within the industrial standard of a maximum of 22R. This value confirms that the use of Bleaching Earth effectively reduces color intensity to a level suitable for consumption and meets trade quality standards. This color change not only improves the visual aspect (clarity) but also demonstrates a reduction in pigments like β -carotene and chlorophyll, which can affect the oil's oxidative stability. The application of Bleaching Earth not only improves the appearance of cooking oil but also enhances its overall quality and shelf life. This shows that agricultural waste-based adsorbents can be an environmentally friendly and economical alternative for the cooking oil processing industry (Kordi et al., 2024).

CONCLUSION

Rice husk was successfully processed into Bleaching Earth using the precipitation method. The synthesized Bleaching Earth met the key parameters of SNI 136336-2000, exhibiting low moisture content (2.48–6.01%), neutral pH (7), and a mesoporous structure. The optimal pore diameter for adsorption was found to be 11–12 nm, achieved with 25 mL NaAlO₂ and 50 minutes of stirring or 35 mL NaAlO₂ and 40 minutes of stirring. The application of this Bleaching Earth significantly reduced the color intensity of used cooking oil, resulting in lighter and clearer oil. These findings confirm that rice husk is a promising, eco-friendly, and low-cost alternative raw material for producing effective Bleaching Earth in palm oil refining.

For future research, it is recommended to optimize synthesis parameters under industrial-scale conditions and to evaluate the large-scale application of this Bleaching Earth in palm oil refineries. Further investigation into adsorption kinetics, regeneration efficiency, and long-term performance stability is also suggested to enhance the scalability and economic feasibility of rice husk-based Bleaching Earth.

ACKNOWLEDGEMENTS

The authors would like to thank the Chemical Engineering Research Laboratory at Universitas Pembangunan Nasional "Veteran" Jawa Timur for providing the facilities and support to conduct this research.

REFERENCES

- [BSN] National Standardization Agency. 2000. Bentonite for Vegetable Oil Bleaching. SNI 136336-2000
- Dahlan, M., & Hariyanto. (2022). Pengaruh kadar air sekam padi terhadap efisiensi pembakaran kompor gasifikasi. *Journal of Energy, Materials, & Manufacturing Technology*, 1(01), 7–11. <https://doi.org/10.61844/jemmttec.v1i01.148>.
- Deutschland, B. (2015). Die folgenden Angaben sind den vom Anmelder eingereichten Unterlagen entnommen (German Patent No. DE 10356894 A1).
- Eleraky, M. I., Razek, T. M. A., Hasani, I. W., & Fahim, Y. A. (2025). Adsorptive removal of lead, copper, and nickel using natural and activated Egyptian calcium bentonite clay. *Scientific Reports*, 15(1), 13050. <https://doi.org/10.1038/s41598-025-95184-7>.
- Eyankware, M. O., Ogwah, C., & Ike, J. C. (2021). A synoptic review of mineralogical and chemical characteristics of clays in the southern part of Nigeria. *Research in Ecology*, 3(2), 32–45. <https://doi.org/10.30564/re.v3i2.3057>.
- Hadi, I., & Sudiarta, W. (2021). Sintesis silika gel dari abu sekam padi dan abu limbah pembakaran batu-bata dengan metode presipitasi. *Jurnal Kimia (Journal of Chemistry)*, 7(1), 31–38.
- Hanipa, P., Fauzia, V., Sari, D. A. P., & Kristiani, A. (2017). Pengaruh variasi waktu hidrotermal terhadap sintesis dan karakterisasi nanokristal zeolit A dari abu sekam padi. *Jurnal Kimia Sains dan Aplikasi*, 20(2), 79–83. <https://doi.org/10.14710/jksa.20.2.79-83>.
- Heryani, H. (2019). Penentuan kualitas degummed bleached palm oil (DBPO) dan refined bleached deodorized palm oil (RBDPO) dengan pemberian Bleaching Earth pada skala industri. *Jurnal Teknologi Industri Pertanian*, 29(1), 11–18. <https://doi.org/10.24961/j.tek.ind.pert.2019.29.1.11>.
- Kordi, M., Goli, S. A. H., & Rostami, S. (2024). Rice husk at a glance: From agro-industrial to modern applications. *Rice Science*, 31(1), 14–32. <https://doi.org/10.1016/j.rsci.2023.08.005>.
- Kumalasari, M.R. dkk. (2024) 'Rice Husk Ash: A Promising Heavy Metal Adsorbent For Wastewater Treatment', *Walisono Journal of Chemistry*, 7(1), pp. 26–36, <https://doi.org/10.21580/wjc.v7i1.18852>.
- Kurniawati, T., Sutrisno, B., & Hidayat, A. (2019). The effect of moisture content on the adsorption capacity of silica-based adsorbent from rice husk ash. *IOP Conference Series: Materials Science and Engineering*, 543, 012058.
- Mading, R., Batu, M. S., Kolo, M. M., & Saka, A. R. (2025). Pembuatan karbon aktif dari tempurung buah lontar (*Borassus flabellifer* L.) sebagai adsorben Rhodamin B. *MJoCE (Mangifera Journal of Chemistry Education)*, 14(1), 10–21.
- Olein, P., & Veronika, N. (2023). Pengaruh konsentrasi Bleaching Earth pada proses pembuatan minyak goreng sawit. *Jurnal Teknologi Pangan dan Gizi*, 6(1), 36–42.
- Plaxedes, S., Edison, M., & Tirivaviri, M. (2023). Bleaching of crude marula oil using activated bentonite and activated marula shells: A comparative analysis. *International Journal of Applied Science and Engineering*, 20(2). [https://doi.org/10.6703/IJASE.202306_20\(2\).004](https://doi.org/10.6703/IJASE.202306_20(2).004).
- Prameswara, G., Diana, S., & Amalia, R. (2023). Studi kinetika ekstraksi silika dari abu sekam limbah penggilingan padi pada Kabupaten Gowa. *Jurnal Ilmu Lingkungan*, 21(4), 974–979. <https://doi.org/10.14710/jil.21.4.974-979>.
- Ramdhani, E. P., Firdaus, M. L., & Elvinawati. (2018). Sintesis $\gamma\text{-Al}_2\text{O}_3$ dari zeolit alam Sumbawa. *Jurnal Zarah*, 6(2), 59–62. <https://doi.org/10.31629/zarah.v6i2.691>,

- Rochdiani, D., Priatna, S. J., & Setiawan, I. (2022). Dinamika produksi padi kaitannya dengan ketahanan pangan di Indonesia. *Jurnal Agribisnis Indonesia*, 1, 15–24.
- Salawudeen, T. O., Alade, A. O., & Kovo, A. S. (2025). Clay characterization and optimisation of bleaching parameters for palm kernel oil using alkaline activated clays. *Journal of Minerals and Materials Characterization and Engineering*, 2(6), 586–597. <https://doi.org/10.4236/jmmce.2025.26060>.
- Silva, S. M., Sampaio, K. A., Ceriani, R., Verhé, R., Stevens, C., & De Greyt, W. (2025). Adsorption of carotenes and phosphorus from palm oil onto acid activated Bleaching Earth: Equilibrium, kinetics and thermodynamics. *Journal of Food Engineering*, 118(4), 341–349. <https://doi.org/10.1016/j.jfoodeng.2025.04.026>.
- Soetaredjo, F. E., Putro, J. N., Ismadji, S., & Ju, Y. (2021). Ecological-safe and low-cost activated-Bleaching Earth: Preparation, characteristics, bleaching performance, and scale-up production. *Journal of Cleaner Production*, 279, 123793. <https://doi.org/10.1016/j.jclepro.2021.123793>.
- Soylu, T. M., Dogan, O., & Kaya, M. (2025). Mesoporous silica aerogels for sunflower oil refining and investigation of their adsorption performance. *Journal of Sol-Gel Science and Technology*, 115(1), 327–348. <https://doi.org/10.1007/s10971-024-06395-9>.
- Tsaousi, et al., (2023). 'Control of silica gel formation in the acidic leaching of CA slag. *Sustainability*', 15(21), 15462. <https://doi.org/10.3390/su152115462>
- Ulandari, R., Muis, L., & Suryadri, H. (2024). Pengaruh waktu terhadap karakteristik zeolit sintesis daun bambu (*Gigantochloa atter*) menggunakan metode hidrotermal dan aplikasinya terhadap penyerapan ion logam Mn^{2+} . *Jurnal Teknologi dan Inovasi Industri*, 05(01), 34–39.
- Yan, S., Chen, X., Wang, J., & Wang, Q. (2022). Characteristics of smoldering on moist rice husk for silica production. *Sustainability*, 14(1). <https://doi.org/10.3390/su14010317>.