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The Effect of Solvent Use on Biodiesel Production from Spent Bleaching Earth (SBE) via Staged *In Situ* Transesterification

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ABSTRACT: This study investigates the effect of solvent and co-solvent systems on biodiesel production from spent bleaching earth (SBE) via staged in situ transesterification. The proposed approach integrates solvent-assisted extraction and transesterification in a staged sequence to enhance oil recovery and fatty acid methyl ester formation from a solid waste feedstock. Methanol–hexane and ethanol–hexane systems were evaluated at various SBE-to-co-solvent ratios and transesterification times. The results indicate that methanol-based systems consistently produced higher biodiesel yields than ethanol-based systems, with optimal performance observed at an SBE-to-co-solvent ratio of 1:3 and a transesterification time of 90 minutes. GC–MS analysis provided chemical evidence of ester formation, revealing the presence of palm oil–derived fatty acid methyl esters, with the highest total methyl ester content (44.74%, area %) obtained under methanol-based conditions at a ratio of 1:3. Overall, the findings highlight the critical role of solvent selection and staged processing in improving biodiesel recovery and ester formation from spent bleaching earth.

Keywords: spent bleaching earth; biodiesel; staged in situ transesterification; solvent system; fatty acid methyl ester

1. Introduction

Indonesia plays a central role in the global palm oil industry, ranking as the world's largest producer and exporter of crude palm oil (CPO). More than 22 of the 34 provinces cultivate oil palm, with Sumatra and Kalimantan contributing over 90% of national production. During the refining process, bleaching represents a critical stage intended to remove pigments, impurities, gums, and free fatty acids through the addition of bleaching earth at approximately 0.5–2% of processed CPO. As the downstream palm oil sector continues to expand, the consumption of bleaching earth has increased accordingly, leading to the generation of substantial quantities of solid waste known as spent bleaching earth (SBE).

SBE is the largest solid waste produced in palm oil and oleochemical refinery industries, typically reaching 6–50 tons per day depending on refinery capacity. This waste contains 20–40% retained oil along with various organic and inorganic components, including pigments, waxes, diglycerides, free fatty acids (FFAs), phenolic compounds, proteins, and trace heavy metals such as Pb and Cd. Owing to its complex chemical composition, improper handling of SBE poses significant environmental risks, such as soil degradation, water contamination, and potential health hazards associated with the inhalation or ingestion of toxic substances. Nevertheless, numerous studies have explored SBE valorization pathways, including its application as an additive in construction materials (Nababan et al., 2023; Sumarno & Prasetyo, 2022), an adsorbent for FFA reduction (Maharani et al., 2022) a raw material for ceramic membrane fabrication (Rahma et al., 2023) and a promising feedstock for biodiesel production ((Sedghamiz et al., 2019; Suryani et al., 2017).

Existing SBE processing methods—such as conventional solvent extraction (Dejkajorn et al., 2021), microwave-assisted extraction (Nugraha et al., 2023), and hybrid esterification–transesterification routes have demonstrated improved oil recovery; however, several technical challenges remain. These challenges are primarily associated with limited solvent penetration into the porous SBE matrix, incomplete oil release, and the presence of high free fatty acid content. Elevated FFA levels are particularly problematic for base-catalyzed transesterification, as FFAs readily react with alkaline catalysts to form soap through saponification. This side reaction reduces biodiesel yield, promotes emulsion formation, and complicates phase separation, ultimately lowering process efficiency.

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Despite significant advances in SBE valorization, biodiesel yields obtained from SBE remain relatively suboptimal due to constrained mass transfer, inefficient reaction pathways, and the combined effects of high FFA content and solid feedstock characteristics. Recent publications from 2023 to 2025 have emphasized the need for improved integration between extraction and reaction stages, particularly through the use of co-solvent systems and staged reaction designs that enhance solvent accessibility, mass-transfer efficiency, and overall conversion performance (Nababan et al., 2023; Rahayu & Nurhayati, 2023; Rahma et al., 2023; Satriaji & Hendrasarie, 2024). Furthermore, (Azizah & Nugroho, 2025; Putra & Wijayanti, 2023; Hidayat & Ramadhani, 2023) have highlighted the importance of optimizing solvent ratios, reaction kinetics, and material utilization strategies to improve waste-to-energy technologies and sustainable fuel production systems.

In this context, the present study proposes the application of a staged in situ transesterification approach supported by a co-solvent system as an integrated strategy to address the limitations of conventional SBE processing. By combining solvent-assisted oil release with staged transesterification within a single processing framework, this approach is expected to enhance oil recovery while mitigating the adverse effects of high FFA content. The novelty of this research lies in the systematic optimization of solvent composition, extraction duration, and reaction conditions to improve biodiesel yield and promote more effective conversion of oil retained in SBE into biodiesel.

2. Materials and Methods

2.1. Materials and Equipments

The primary raw material used in this study was spent bleaching earth (SBE) obtained from the PT XYZ Edible Oil Processing Plant in Padang, Indonesia. The chemicals employed included n-hexane (Merck, 99.5%) as a co-solvent, methanol and ethanol (Merck, analytical grade) as alcohol reactants, potassium hydroxide (KOH, Merck, 99.5%) as a base catalyst, and sulfuric acid (H_2SO_4, Merck, 99.5%) as an acid catalyst. Distilled water was used for washing and sample preparation.

The main equipment used in the experiments comprised a three-neck round-bottom flask equipped with a condenser, magnetic stirrer, heating mantle, vacuum pump, Büchner funnel, rotary evaporator, oven, desiccator, and standard laboratory glassware, including Erlenmeyer flasks, beakers, and measuring cylinders.

2.2. Biodiesel Production by Staged Transesterification

Biodiesel production was conducted using a staged in situ transesterification approach in which extraction and transesterification were performed sequentially within the same reaction vessel. Methanol and ethanol were employed as alcohol reactants, while n-hexane was used as a co-solvent to enhance oil extraction from the SBE matrix.

In the first stage, a predetermined amount of SBE (100 g) was contacted with a solvent–co-solvent mixture at various SBE-to-co-solvent ratios (1:1, 1:2, 1:3, and 1:4, w/v). The solvent-to-co-solvent ratio was maintained at 1:1. Sulfuric acid was added as an acid catalyst at a concentration of 1% (v/w, relative to SBE mass), and the mixture was heated at 65 °C for a specified extraction–reaction period to facilitate oil release and suppress saponification.

In the second stage, base-catalyzed transesterification was initiated by adding potassium hydroxide (KOH) at 1% (w/w, relative to SBE mass), pre-dissolved in the corresponding alcohol. The reaction temperature was maintained at 60 °C, and transesterification time was varied (30, 60, and 90 minutes) to evaluate its effect on biodiesel yield and ester formation.

Upon completion of the reaction, the solid SBE residue was separated from the liquid phase using vacuum filtration. The solvent was removed from the biodiesel phase using a rotary evaporator. The resulting crude biodiesel was washed with hot distilled water until neutral pH was achieved and subsequently dried in an oven prior to further analysis. The same procedure was applied for both methanol–hexane and ethanol–hexane solvent systems.

Biodiesel yield was subsequently determined based on the initial oil content of the spent bleaching earth (SBE) feedstock. The average oil content of the SBE used in this study was 19.37 g per 100 g of SBE, and biodiesel yield was calculated using the following equation (Eq 1).

$$\text{Biodiesel yield (\%)} = \frac{m_{\text{biodiesel}}}{m_{\text{oil,initial}}} \times 100 \qquad (1)$$

where $m_{\text{biodiesel}}$represents the mass of biodiesel obtained after solvent removal and washing, and $m_{\text{oil,initial}}$represents the initial oil content present in the SBE feedstock.

Following biodiesel recovery and drying, the chemical composition of the resulting product was further examined to verify fatty acid methyl ester (FAME) formation. The FAME profile of the biodiesel samples was analyzed using gas chromatography–mass spectrometry (GC–MS) equipped with a capillary column suitable for methyl ester separation. Chromatographic data were acquired in total ion current (TIC) mode.

The individual methyl ester components were identified through comparison of their mass spectra with reference data from the NIST mass spectral library. The relative abundance of each FAME was expressed as peak area percentage, without external calibration, to provide a comparative assessment of ester formation under different solvent systems and operating conditions.

3. Results and Discussion

In situ transesterification has been widely recognized as an effective technique for converting oil-bearing solid residues into biodiesel, particularly when extraction and reaction steps are properly integrated to reduce processing time and operational complexity. In the present study, an initial attempt involving direct in situ transesterification—by simultaneously mixing solvent, co-solvent, and catalyst with SBE and reacting for 2 hours at 60 °C—resulted in negligible biodiesel formation. This outcome can be attributed to insufficient oil release from the solid SBE matrix, which limited alcohol–oil contact during the reaction. Similar limitations have been reported by (Mat et al., 2011) and (Ng et al., 2021), who observed that direct in situ conversion without a prior extraction stage often leads to restricted mass transfer, excessive emulsion formation, and poor phase separation.

Furthermore, the clear phase separation observed after washing indicates reduced emulsion formation, supporting the findings of (Rahma et al., 2023), who emphasized the importance of optimizing solvent–solid interactions to improve settling behaviour between biodiesel and glycerol phases. The golden-yellow appearance of the biodiesel obtained under optimized conditions is therefore presented only as a qualitative indication of improved phase separation rather than as a measure of fuel quality.

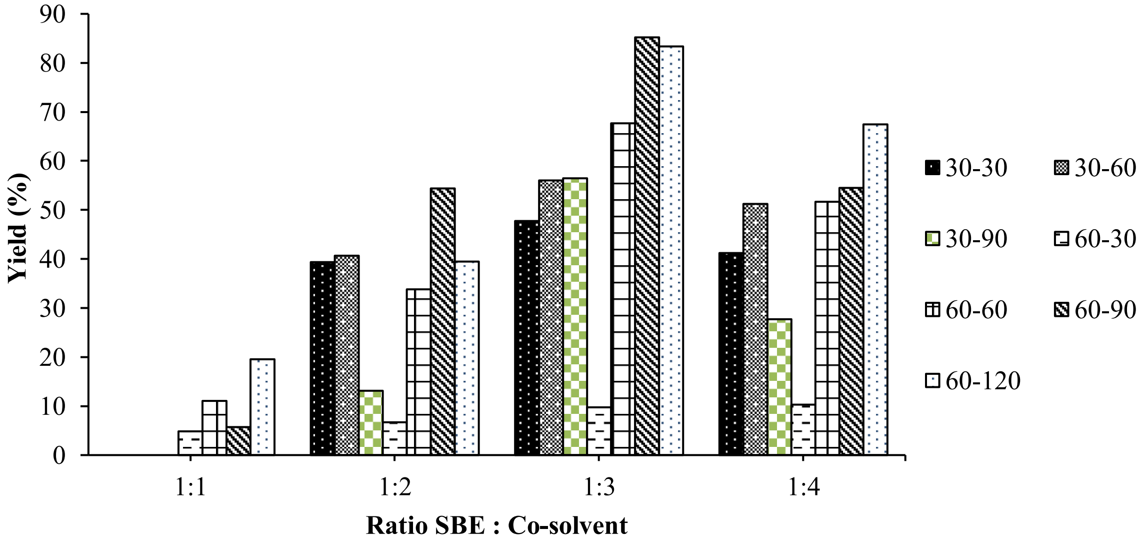

Figure 1. The Effect of SBE and Co-solvent ratio on Biodiesel at different extraction - transesterification times (min)

During solvent removal using a rotary evaporator, distinct liquid layers corresponding to biodiesel and glycerol phases were initially observed. However, biodiesel recovery during the washing stage was unsuccessful, as a significant fraction of the product remained dissolved in the washing medium. This behaviour is consistent with the findings of (Lee et al., 2020), who reported that high free fatty acid (FFA) content combined with improper solvent balance can promote biodiesel solubilization in the aqueous phase, resulting in substantial product losses.

To overcome these limitations, the experimental procedure was modified based on insights from previous studies. (Sedghamiz et al., 2019) Demonstrated that staged or gradual solvent addition significantly improves oil release from SBE and enhances transesterification efficiency. Accordingly, this study implemented a two-stage process comprising an initial extraction stage (30–60 min) followed by a transesterification stage (30–90 min). The staged extraction step facilitated solvent penetration into the porous SBE structure, promoting triglyceride solubilization prior to base-catalyzed transesterification.

The improved biodiesel recovery achieved using the staged approach is consistent with the observations of (Mana et al., 2020), who reported that extended extraction residence time enhances solvent–solid interaction and oil diffusion.

As shown in Figure 1, extraction times of 30 and 60 minutes were evaluated in the first stage prior to alcohol and catalyst addition. This staged extraction strategy effectively enhanced oil release from the solid matrix, consistent with the work of (Sedghamiz et al., 2019) who reported that controlled solvent–solid contact improves triglyceride diffusion. In the second stage, transesterification times of 30, 60, and 90 minutes were investigated. Longer reaction durations generally promoted higher biodiesel recovery, reflecting more complete conversion, in agreement with (Azizah & Nugroho, 2025) who highlighted the role of optimized residence time in improving biodiesel yield.

Table 1 presents the biodiesel yield calculated based on the initial oil content of the spent bleaching earth feedstock (19.37 g per 100 g SBE) under different SBE-to-co-solvent ratios and extraction–transesterification time combinations. The data indicate that biodiesel yield increased with increasing solvent ratio and reaction time, reaching a maximum at an SBE-to-co-solvent ratio of 1:3 and a transesterification time of 90 minutes. This quantitative trend provides the basis for the comparative analysis discussed in the following sections.

Table 1. Biodiesel yield based on initial oil content of spent bleaching earth (19.37 g per 100 g SBE) under different SBE-to-co-solvent ratios and reaction times. Note: 60 minute (extraction time) – 120 minutes (transesterification time)

SBE : solvent Ratio	Yield (gram)						
	60 -120	60-30	60-60	60-90	30-30	30-60	30-90
1 : 1	19.57	4.86	11.02	5.69	0,00	0,00	0,00
1 : 2	39.49	6.7	33.85	54.41	39.4	40.68	13.13
1:3	83.38	9.77	67.68	85.18	47.81	56,00	56.49
1:4	67.42	10.26	51.65	54.55	41.21	51.29	27.76

Overall, the staged extraction–reaction sequence applied in this study significantly improved mass transfer, enhanced oil recovery, and minimized biodiesel losses during washing. These results indicate that gradual solvent addition combined with optimized reaction durations provides an effective strategy for improving biodiesel production from SBE and other solid, high-residue feedstocks.

3.1. The Effect of Co-solvent Ratio on Yield Acquisition

The solvent-to-solid ratio plays a crucial role in determining the efficiency of oil extraction and subsequent biodiesel formation from spent bleaching earth (SBE). Variations in solvent proportion directly influence solvent penetration into the SBE matrix, the dissolution of trapped triglycerides, and the effectiveness of the transesterification reaction. Table 2 show the effect of different solvent ratios on biodiesel yield.

At a solvent ratio of 1:1, biodiesel yield was relatively low, indicating that the solvent volume was insufficient to effectively penetrate the porous structure of SBE and dissolve the retained oil. Limited solvent diffusion at this ratio restricts oil–solvent contact, resulting in incomplete extraction of triglycerides and consequently low biodiesel formation (Sulihatimarsyila et al., 2021).

Increasing the solvent ratio to 1:2 led to a noticeable improvement in biodiesel yield. The higher solvent volume enhanced solvent–solid interaction and facilitated greater oil dissolution from the SBE matrix. This condition represents a more favourable balance between solvent availability and extraction efficiency, allowing a larger fraction of trapped oil to participate in the transesterification reaction.

A further increase in solvent ratio to 1:3 resulted in the highest biodiesel yield obtained in this study. At this ratio, solvent penetration into the SBE pores was sufficient to dissolve most of the retained triglycerides, thereby maximizing oil availability for transesterification. Improved mass transfer under these conditions enabled more efficient conversion of extracted oil into biodiesel, consistent with observations reported by Lee et al., 2020

However, increasing the solvent ratio beyond 1:3 did not lead to further yield enhancement. At a ratio of 1:4, biodiesel yield showed no significant improvement and tended to decrease slightly. This behaviour can be attributed to solvent saturation, where most extractable oil has already been dissolved, and additional solvent no longer contributes to increased oil recovery. Excessive solvent usage under these conditions results in inefficient resource utilization without corresponding gains in biodiesel production.

Overall, the results demonstrate the existence of an optimal solvent ratio for biodiesel production from SBE. A solvent ratio of 1:3 provided the most effective balance between solvent volume, oil extraction capability, and mass transfer efficiency, leading to maximum biodiesel yield. Ratios above this optimum were ineffective and economically unfavourable due to diminishing returns. These findings highlight the importance of solvent ratio optimization, alongside other process parameters such as extraction time, temperature, and solvent type, in enhancing the efficiency of biodiesel production from SBE.

3.2. The Effect of Co-solvent Ratio and Operating Time on Biodiesel Yield Acquisition

Transesterification is the key reaction stage in which triglycerides are converted into fatty acid methyl esters in the presence of alcohol and catalyst. Reaction time is therefore a critical parameter influencing the extent of triglyceride conversion and overall biodiesel recovery. Insufficient reaction time may result in incomplete conversion, while excessively prolonged reaction durations can promote side reactions, such as saponification or emulsion formation, which adversely affect product separation and yield.

As shown in Table 2, biodiesel yield increased with transesterification time for all evaluated solvent conditions. At an SBE-to-co-solvent ratio of 1:4, biodiesel production during the initial 30 minutes remained relatively low, indicating that the reaction had not yet reached an effective conversion stage. A substantial increase in biodiesel yield was observed as the reaction time was extended to 60 minutes, reflecting improved triglyceride conversion and enhanced interaction between the alcohol and extracted oil.

The highest biodiesel yield was achieved at a reaction time of 90 minutes. At this duration, the transesterification reaction approached equilibrium, allowing a greater fraction of triglycerides to be converted into methyl esters. Shorter reaction times were insufficient to fully convert the extracted oil, leaving residual triglycerides or free fatty acids in the reaction mixture. These trends are consistent with the findings reported by (Azizah & Nugroho, 2025; Ng et al., 2021) Ng et al. (2021) and Nugraha et al. (2023), who emphasized that reaction durations in the range of 80–90 minutes are generally required to achieve high conversion efficiency during transesterification of solid-derived feedstocks.

Tabel 2. Effect of co-solvent ratio and operating time (extraction:transtesterification) on biodiesel yield

Co-solvent	Ratio	60: 60 (min)			60: 90 (min)		
		Biodiesel		Yield	Biodiesel		Yield
		gram	ml	%	gram	ml	%
Methanol	1:1	2.13	2.4	11.01	1.10	1	5.68
	1:2	6.55	7.5	33.84	10.53	16	54.39
	1:3	13.11	15.0	67.66	16.49	19	85.15
	1:4	10.00	11.5	51.61	10.56	12	54.53
Ethanol	1:1	6.27	9.0	32.38	5.52	7	28.51
	1:2	10.52	16.0	54.31	5.04	4	26.03
	1:3	11.59	15.0	59.84	13.07	17	67.48
	1:4	11.74	14.5	60.61	11.12	15	57.41

Extending the reaction time beyond 90 minutes did not result in further yield improvement and, in some cases, led to a slight decline in biodiesel recovery. This behaviour is attributed to the increased likelihood of side reactions, including soap formation and partial degradation of methyl esters, as well as enhanced emulsion formation between biodiesel and glycerol phases. Similar observations were reported by (Lee et al., 2020), who noted that prolonged transesterification times may reduce process efficiency due to reverse reactions and water-induced saponification.

From a process optimization perspective, establishing an optimal transesterification time of 90 minutes offers a balance between reaction completeness and operational efficiency. Operating beyond this duration increases energy consumption and catalyst exposure without providing proportional gains in biodiesel yield. Therefore, optimizing the reaction time at 90 minutes is essential not only for maximizing biodiesel recovery but also for improving overall process efficiency and economic feasibility, as supported by previous studies (Mana et al., 2020)

3.3. The effect of Reactants on Biodiesel Yield

In this biodiesel production process, methanol and ethanol were used to evaluate how each solvent influences biodiesel yield. The experimental results indicated that methanol produced higher yields across most reaction conditions. This finding aligns with previous studies reporting that methanol's low molecular weight and high polarity enhance its interaction with triglycerides, allowing transesterification to proceed efficiently even at lower temperatures. Methanol also exhibits higher reactivity than ethanol, resulting in faster conversion rates and shorter required reaction times, as similarly observed by (Encinar et al., 2011). These characteristics, combined with its low cost and widespread industrial availability, explain why methanol is commonly preferred in commercial biodiesel production.

Conversely, although ethanol tended to produce slightly lower yields in this study, it offers notable environmental advantages because it is derived from renewable agricultural sources. Ethanol-based transesterification can yield biodiesel with physical properties closer to conventional diesel, particularly in terms of viscosity and cetane number.

Similar to the results obtained in this experiment, earlier research also noted that ethanol often requires more rigorous reaction conditions due to its lower reactivity and more complex interaction with triglycerides (Gui et al., 2008). Nevertheless, under optimized conditions, ethanol can still produce competitive biodiesel yields while simultaneously reducing dependence on fossil-derived methanol and supporting renewable fuel initiatives.

In this study, methanol and ethanol were evaluated as alcohol reactants to investigate their influence on biodiesel yield during staged in situ transesterification. The experimental results demonstrated that methanol consistently produced higher biodiesel yields than ethanol under comparable operating conditions. This behavior can be attributed to the physicochemical properties of methanol, including its lower molecular weight, higher polarity, and greater reactivity toward triglycerides.

These properties enhance alcohol–oil miscibility and facilitate faster transesterification kinetics, allowing efficient ester formation even at relatively mild reaction conditions. Similar observations have been reported by (Encinar et al., 2011), who noted that methanol enables higher conversion efficiency and shorter reaction times compared to higher alcohols.

In contrast, ethanol-based transesterification resulted in slightly lower biodiesel yields in this study. This outcome is consistent with previous reports indicating that ethanol exhibits lower reactivity and more complex interactions with triglycerides, often requiring more severe reaction conditions to achieve comparable conversion levels(Gui et al., 2008). Despite this limitation, ethanol offers important environmental advantages, as it can be derived from renewable agricultural resources and contributes to reduced dependence on fossil-based methanol. Under optimized solvent ratios and reaction times, ethanol remains a viable alternative alcohol for biodiesel production, particularly in the context of sustainable fuel development.

Overall, the comparative results indicate that methanol is more effective than ethanol in promoting biodiesel yield under staged in situ transesterification conditions. The superior performance of methanol is primarily associated with its favorable reactivity and mass-transfer characteristics, while ethanol remains a promising renewable alternative when environmental considerations are prioritized and reaction conditions are appropriately optimized.

To further verify that the observed yield trends were associated with chemical ester formation rather than solely physical extraction, the liquid biodiesel product obtained under optimal conditions was subsequently analysed by GC–MS to identify and evaluate fatty acid methyl ester formation.

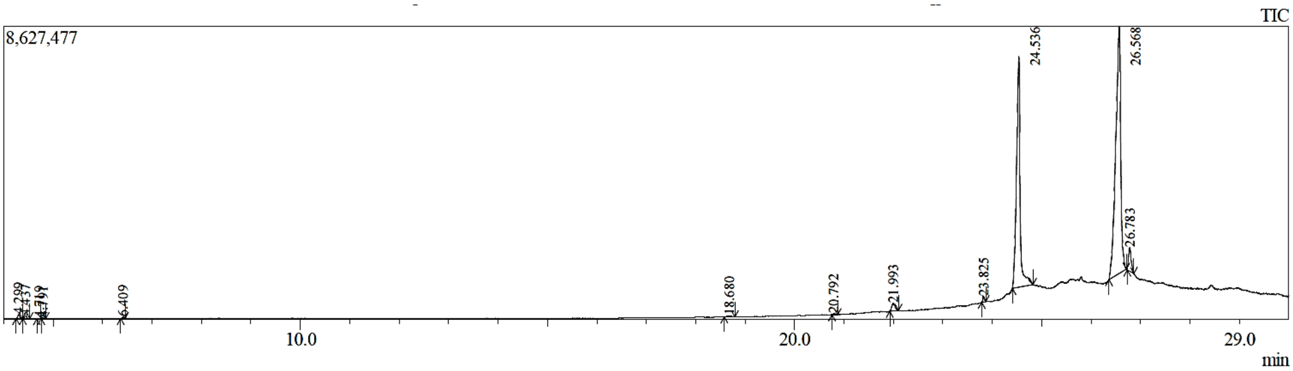

Figure 2. Representative GC–MS chromatogram (TIC mode) of biodiesel produced from spent bleaching earth via staged in situ transesterification using a methanol–hexane system at an SBE-to-co-solvent ratio of 1:3

3.4. Fatty Acid Methyl Ester (FAME) Composition

The formation of fatty acid methyl esters during staged in situ transesterification was examined using GC–MS analysis to provide chemical evidence of biodiesel production from spent bleaching earth. A representative GC–MS chromatogram obtained from the methanol–hexane system at an SBE-to-co-solvent ratio of 1:3 is shown in Figure 2. This condition was selected because it corresponded to the optimum operating parameters identified in the biodiesel yield analysis. The chromatogram was recorded in total ion current (TIC) mode after solvent removal and washing of the biodiesel phase.

As shown in Figure 2, several dominant peaks appeared within the retention time range of approximately 18–27 minutes, which is typical for long-chain fatty acid methyl esters originating from palm oil–based feedstocks. The major components detected under these conditions included methyl palmitate (C16:0), methyl oleate (C18:1), and methyl stearate (C18:0). The presence of these methyl esters confirms that triglycerides retained in the spent bleaching earth were successfully converted into fatty acid methyl esters through the staged extraction–reaction process, despite the solid nature of the feedstock.

The relative abundance of fatty acid methyl esters, expressed as GC–MS peak area percentages, further supports this observation. Under methanol-based conditions at an SBE-to-co-solvent ratio of 1:3, the total methyl ester content reached 44.74% (area %), which was the highest among the evaluated solvent systems and ratios. This result is consistent with the biodiesel yield trends discussed in Sections 3.1–3.3, indicating that operating conditions favoring enhanced oil extraction also promote more effective ester formation.

Compared with ethanol-based systems, methanol-based transesterification resulted in higher relative methyl ester formation. This behaviour can be attributed to the higher polarity and reactivity of methanol, which improve alcohol–oil interactions and mass transfer during transesterification. Consequently, methanol facilitates more efficient conversion of extracted triglycerides into methyl esters under optimized conditions. It should be noted that the GC–MS results are reported as relative peak area percentages and are intended for comparative evaluation of ester formation rather than absolute quantification or fuel quality assessment.

Overall, the combined biodiesel yield and GC–MS results demonstrate that the staged extraction–reaction strategy, together with appropriate solvent selection and co-solvent ratio optimization, plays a critical role in enhancing both oil recovery and fatty acid methyl ester formation from spent bleaching earth. These findings confirm the effectiveness of the proposed approach for valorising solid industrial waste into biodiesel.

4. Conclusion

This study indicates that staged in situ transesterification is an effective approach for converting oil retained in spent bleaching earth into biodiesel. The integration of solvent-assisted extraction and transesterification within a staged process significantly enhances oil recovery and facilitates fatty acid methyl ester formation from a solid industrial waste feedstock.

Among the evaluated operating parameters, methanol-based systems consistently outperformed ethanol-based systems, with optimal performance observed at an SBE-to-co-solvent ratio of 1:3. Under these conditions, the staged process promoted efficient oil extraction and favorable transesterification behavior, resulting in the highest biodiesel yield trend among the tested conditions. The superior performance of methanol is attributed to its higher polarity and reactivity, which enhance alcohol–oil interaction and transesterification kinetics.

GC–MS analysis provided chemical evidence of successful ester formation, revealing the presence of dominant palm oil–derived fatty acid methyl esters, including methyl palmitate, methyl oleate, and methyl stearate. The relative methyl ester composition (expressed as peak area percentages) was consistent with the observed yield trends, confirming that solvent selection and co-solvent ratio optimization play critical roles in governing biodiesel production efficiency.

Overall, the findings highlight the importance of staged extraction–reaction strategies and solvent optimization in improving biodiesel production from spent bleaching earth. This approach offers a promising pathway for valorizing solid industrial waste into renewable energy resources while supporting sustainable waste-to-energy applications.

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Statement

During the preparation of this work, the authors used ChatGPT 4o to improve the English language and proofread the text. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

CRediT authorship contribution statement

Melysa Putri: Conceptualization, Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Investigation. Miftahurrahmah: Conceptualization, Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Investigation. Netri Elisma: Resources, Data curation, Formal analysis, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Data availability

Data that support the findings of this study are available from the corresponding author upon reasonable request.

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