

Ethanol-Based Soxhlet Extraction of Residual Oil from Spent Bleaching Earth: Yield Analysis and Process Evaluation

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ABSTRACT

Spent Bleaching Earth (SBE), a by-product of the vegetable oil refining industry, contains a significant amount of residual oil that remains trapped within its porous structure. Efficient recovery of this oil can enhance resource utilization and contribute to waste minimization. This study investigates the effectiveness of Soxhlet extraction using ethanol as the solvent for recovering residual oil from SBE. A sample of 10 g of SBE was subjected to three extraction cycles, with individual cycle durations of 27 minutes 05 seconds, 33 minutes 53 seconds, and 36 minutes 26 seconds. Following solvent evaporation, the mass of the recovered extract was determined to be 1.4823 g. The extraction yield was subsequently calculated as 14.823%, indicating moderate efficiency under the operating conditions employed. The results highlight that Soxhlet extraction provides a consistent and reproducible method for oil recovery due to its continuous hot solvent circulation, which facilitates effective dissolution of extractable components. However, the moderate yield suggests that ethanol, as a semi-polar solvent, is not the most optimal choice for extracting non-polar oil residues. Factors such as solvent polarity, extraction time, reflux temperature, and sample particle size likely influenced the

efficiency of the extraction process. Despite these limitations, the study demonstrates the potential of Soxhlet extraction as a baseline method for assessing recoverable oil in SBE. Future research aimed at optimizing solvent type, extraction conditions, and process parameters could significantly improve yield and contribute to more sustainable valorization of SBE.

Keywords: Soxhlet extraction, Spent Bleaching Earth (SBE), ethanol solvent, extraction yield, oil recovery

INTRODUCTION

In the purification process of vegetable oils, bleaching earth is commonly used to remove pigments, impurities, and reactive compounds that may cause discoloration or accelerate oil degradation. After undergoing the bleaching process, this material is referred to as Spent Bleaching Earth (SBE). SBE typically retains a substantial amount of residual oil, ranging from 20–40% of its total weight, making it a valuable yet underutilized by-product in the vegetable oil industry [1,2].

Extraction plays a fundamental role in chemical, pharmaceutical, and food industries as a method for isolating active compounds from natural materials using appropriate solvents. Among the various extraction techniques, Soxhlet extraction

remains one of the most widely adopted due to its ability to facilitate continuous solvent circulation, enabling repeated washing of the sample and maximizing the recovery of target compounds [3,4,5].

Recovering the residual oil trapped within SBE is one of the promising valorization strategies. The Soxhlet extraction method is particularly advantageous for this purpose because its continuous reflux mechanism ensures efficient solubilization and transfer of oil from the solid matrix into the solvent. This constant solvent cycling at a controlled temperature allows the extraction to proceed until equilibrium is reached, resulting in higher oil recovery compared to conventional batch extraction methods [5,6]. Recent advancements in SBE valorization highlight growing interest in converting industrial waste into economically valuable resources through optimized extraction techniques, green solvents, and integrated biorefinery approaches. Soxhlet extraction remains a benchmark method for evaluating extraction efficiency due to its reproducibility, simplicity, and compatibility with diverse solvent systems. Contemporary studies increasingly focus on enhancing extraction performance through solvent engineering, process intensification, and comparison with modern techniques such as ultrasound-assisted and supercritical fluid extraction [7,2,8]. Within this context, investigating Soxhlet-based recovery of residual oil from SBE provides essential baseline data that support technological development in waste minimization, resource recovery, and sustainable processing within the vegetable oil industry.

MATERIALS & METHODS

Extraction Procedure

- Prepare the sample by wrapping it in filter paper or placing it inside a cellulose thimble.
- Secure the thimble with thread, leaving approximately 20 cm of extra thread to facilitate removal after extraction.

- Ensure the height of the thimble does not exceed the capillary tube located on the side of the Soxhlet extractor.
- Insert the thimble into the extractor and add a small weight to prevent it from floating during extraction.
- Place boiling stones into the Soxhlet flask.
- Assemble the complete Soxhlet apparatus (flask, extractor body, and condenser).
- Apply a thin layer of vacuum grease to all glass joints to ensure airtight connections.
- Check the tightness of the joints periodically to prevent solvent loss during the process.
- Add ethanol through the condenser until the solvent level exceeds the height of the capillary tube, allowing it to drain completely into the flask.
- Add additional solvent until the extractor chamber is filled to approximately two-thirds of the thimble height.
- Start the flow of cooling water through the condenser.
- Heat the mantle or hot plate carefully to initiate solvent boiling.
- Perform the extraction under reflux for three siphon cycles, or until the solvent color in the extractor no longer changes.
- After extraction, remove the thimble from the apparatus.
- Separate the solvent from the extracted oil by distilling it directly using the same Soxhlet setup.
- Continue distillation until the condensed solvent collected in the extractor remains below the height of the capillary tube.
- Repeat the distillation process until a concentrated extract is obtained.

Yield Analysis

The extraction process was carried out using a standard Soxhlet apparatus following a modified

The extraction yield was determined by comparing the mass of the extract obtained to

the initial mass of the sample. Yield was calculated using the following equation:

$$\text{Yield (\%)} = \frac{\text{Final mass of extract}}{\text{Initial mass of sample}} \times 100\%$$

This calculation provides a quantitative measure of the extraction efficiency, indicating the proportion of material successfully recovered relative to the amount of sample used at the beginning of the process. A higher yield percentage reflects a more effective extraction process, while lower values suggest incomplete recovery or potential losses during processing. This parameter is essential for evaluating the performance of the extraction method and comparing different operational conditions or extraction technologies [9].

RESULT & DISCUSSION

The Soxhlet extraction of Spent Bleaching Earth (SBE) was conducted using ethanol as the extraction solvent. A total of 10 g of SBE were placed in a thimble and subjected to continuous solvent reflux. The extraction was carried out for three complete cycles, each with different durations due to variations in heating and solvent circulation rates [10,11]. Upon completion, the solvent was evaporated to determine the mass of the recovered extract. The key experimental results are summarized in Table 1.

Table 1. Summary of Soxhlet Extraction Data

Parameter	Result
Initial sample mass (SBE)	10 g
Initial solvent volume	200 mL
Remaining solvent volume	175 mL
Cycle time – Cycle 1	27 min 05 s
Cycle time – Cycle 2	33 min 53 s
Cycle time – Cycle 3	36 min 26 s
Mass of empty dish	41.901 g
Mass of dish + extract	42.8824 g
Mass of extract	1.4823 g
Extraction yield	14.823%

The extraction yield was calculated based on the mass of the recovered extract relative to the initial mass of the sample, using the equation:

$$\text{Yield (\%)} = \frac{\text{Final mass of extract}}{\text{Initial mass of sample}} \times 100\%$$

The final extract mass of 1.4823 g corresponds to a yield of 14.823%, indicating that approximately 1.48 g of residual oil were successfully recovered from 10 g of SBE. This value falls within a moderate range for SBE extraction using polar or semi-polar solvents, reflecting both the effectiveness and the limitations of ethanol under the given operational conditions [12,13].

The moderate yield suggests that while Soxhlet extraction was successful in recovering residual oil, the process did not achieve maximum extraction efficiency [14,15]. Several factors likely contributed to this outcome:

1. **Solvent Polarity**
Ethanol is a semi-polar solvent capable of dissolving certain non-polar components such as triglycerides. However, its solubility capacity for fully non-polar compounds is lower compared to solvents like n-hexane. This polarity mismatch may have limited the extraction of hydrophobic oil residues strongly bound within the SBE matrix.
2. **Extraction Time and Cycle Duration**
The durations of the three cycles increased progressively (27, 33, and 36 minutes), which may indicate decreasing solvent flow rate as the extraction progressed. Longer cycle times do not necessarily equate to improved extraction and may reflect reduced mass transfer efficiency.
3. **Temperature and Reflux Stability**
The extraction temperature directly influences solvent vaporization and diffusion into the sample matrix. Variations in heating intensity may have affected the consistency of the reflux rate, potentially reducing extraction uniformity.
4. **Particle Size and Matrix Compactness**
SBE has a porous but compact structure that can trap residual oil within its layers. If particle size is not sufficiently reduced,

solvent penetration may be limited, lowering extraction yield.

Despite the moderate yield, the Soxhlet method remains advantageous for SBE oil recovery. Its continuous solvent circulation ensures repeated washing of the sample with freshly condensed hot solvent, thereby enhancing dissolution of extractable components. The method is particularly effective for laboratory-scale extraction where reproducibility and thoroughness are required [10, 16,17].

The yield of 14.823% demonstrates that Soxhlet extraction under the conditions used in this study is capable of liberating a notable portion of residual oil from SBE. However, further optimization is possible. Adjustment of variables such as:

- selection of a more non-polar solvent (e.g., n-hexane),
- extended extraction duration or increased number of cycles,
- controlled heating for stable reflux,
- reduction of sample particle size, could significantly enhance extraction efficiency.

The results clearly indicate that Soxhlet extraction is an effective method for recovering oil from SBE, although ethanol is not the most optimal solvent for maximum oil recovery. The yield obtained provides insight into the extractable oil fraction and highlights the importance of solvent selection and process parameters in optimizing SBE valorization [14,18,19]. These findings support the use of Soxhlet extraction as a baseline method for studying SBE oil recovery, while also providing direction for improving extraction protocols in future work.

CONCLUSION

This study demonstrated that Soxhlet extraction can effectively recover residual oil from Spent Bleaching Earth (SBE), yielding 1.4823 g of extract from a 10 g sample, corresponding to a recovery rate of 14.823%. The continuous reflux mechanism inherent to the Soxhlet system allowed for repeated solvent-sample contact, resulting in

measurable extraction of oil from the SBE matrix. These findings confirm the suitability of Soxhlet extraction as a reliable laboratory-scale technique for evaluating the extractable oil fraction in SBE.

However, the moderate yield obtained in this study also highlights the limitations of using ethanol as the extraction solvent. As a semi-polar solvent, ethanol dissolves only part of the non-polar oil components, which likely constrained the overall recovery efficiency. Factors such as solvent polarity, reflux stability, extraction time, and sample matrix characteristics were identified as contributors to the observed yield variation. Overall, this work provides baseline data on SBE oil recovery using Soxhlet extraction and underscores the potential for optimizing process parameters. Future studies may achieve higher yields by employing more non-polar solvents such as n-hexane, increasing the number of extraction cycles, refining temperature control, or reducing sample particle size. Such improvements would enhance the valorization potential of SBE and support more sustainable utilization of by-products in the vegetable oil industry.

Declaration by Authors

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