Effect of Extraction and Solvent Removal Methods on Oil Yield of *Sterculia quadrifida* R.Br Seeds

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Abstract. Oil yield obtained from plant materials can be influenced by both extraction techniques and solvent removal processes. *Sterculia quadrifida* R.Br seeds have potential as an alternative source of vegetable oil source. However, limited information is available regarding how different extraction evaporation combinations influence oil recovery efficiency. This study compared oil yield obtained from *Sterculia quadrifida* R.Br seeds using two extraction methods combined with different solvent removal techniques: Soxhlet extraction followed by rotary evaporation and maceration followed by distillation. Extraction was performed using n-hexane and oil yield was calculated based on dry sample weight. Each experiment was conducted in triplicate and analyzed using an independent sample t-test. The maceration-distillation method produced an oil yield of 30.95 ± 0.68%, while Soxhlet-rotary evaporation method yielded 30.65 ± 1.00%. Statistical analysis showed no significant difference between two methods ($p > 0.05$), indicating comparable extraction efficiency. The result suggests that oil recovery is not solely determined by extraction temperature or duration but also by solvent material interaction time and evaporation conditions. This study provides preliminary quantitative evidence that different combinations of extraction and solvent removal techniques may produce similar oil yields, offering flexibility in process selection depending on operational considerations.

1 Introduction

Vegetable oil is an essential component in the food, pharmaceutical, and cosmetic industries. The demand for alternative vegetable oil sources continues to increase due to the development of functional food industries and growing awareness of local biological resource utilization. One promising species plant with potential as a vegetable oil source is *Sterculia quadrifida* R.Br, locally known as faloak, whose seeds contain lipid component with potential in food products and other value-added applications [1].

Among the various unit operations involved in oil processing, extraction remains one of the most critical steps because it directly determines both the quality and quantity of the

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extracted oil. The initial oil content of seeds is a major factor influencing the choice of processing and extraction methods [2,3].

Oil extraction refers to the separation of triglycerides from seeds using chemical, physical, or mechanical techniques to maximize yield while minimizing quality degradation [4]. The oil yield obtained is strongly influenced by the extraction method and solvent removal technique [5]. Solvent extraction is widely recognized as an effective method for oil recovery due to its high lipid solubilization efficiency and higher oil recovery compared to mechanical pressing [6].

Conventional extraction methods such as Soxhlet extraction and maceration differ substantially in process characteristics. Soxhlet extraction involves continuous solvent reflux at elevated temperature, promoting rapid mass transfer, whereas maceration operates at lower temperature with extended solvent contact time, allowing gradual diffusion of oil from the plant matrix [7].

In addition to extraction, solvent evaporation plays an important role in determining oil recovery. Rotary evaporation operates under reduced pressure and relatively low temperature, whereas distillation typically occurs at atmospheric pressure and higher temperature, which may influence solvent separation efficiency and oil retention [8].

Although many studies compare extraction methods, limited research evaluates extraction and solvent removal as an integrated system. Understanding the combined influence of these processes is essential for optimizing oil recovery from underutilized plant resources.

This study aimed to compare the oil yield of *Sterculia quadrifida* R.Br seeds obtained using two combinations of extraction and solvent removal methods: Soxhlet-rotary evaporation and maceration-distillation.

2 Materials and Methods

2.1 Raw Material Preparation and Equipment

Seeds of *Sterculia quadrifida* R.Br were oven-dried at 50°C for 6 h until moisture content was below 10%. The dried seeds were ground and sieved to 60 mesh particle size to ensure uniform extraction. The solvent used was analytical grade n-hexane. Equipment included an oven, heating mantle, grinder, desiccator, 60-mesh sieve, analytical balance, Soxhlet apparatus, distillation apparatus, rotary evaporator, glassware, filter paper, and magnetic stirrer.

2.2 Extraction Procedures

Two extraction-evaporation system were evaluated:

2.2.1 Soxhlet Extraction Followed by Rotary Evaporation

Fifty grams of seed powder were extracted with 350 mL n-hexane using Soxhlet extraction for 6 h at 69-70°C. The extract was concentrated using a rotary evaporator at 40°C and 190 mbar for 40 min to obtain the crude oil.

Fig. 1. Soxhlet Extraction and Rotary Evaporation Process.

2.2.2 Maceration Followed by Distillation

One hundred grams of seed powder were macerated with 350 mL n-hexane at room temperature (28–30°C) for 72 h with periodic stirring. The mixture was filtered, and the solvent was removed by distillation at 68–70°C for 120 min at atmospheric pressure.

Fig. 2. Maceration and Distillation Extraction Process.

2.3 Oil Yield Determination

Following the solvent removal, the extracted oil samples were stored in airtight amber glass vials at 4°C to prevent oxidative degradation prior to further analysis. Oil yield (%) was calculated based on the ratio of extracted oil mass to dry sample mass following AOCS standard methods [9], using the equation:

$$\text{Yield (\%)} = \frac{Weight\ of\ Oil\ Extraction\ (g)}{Weight\ of\ Initial\ Dry\ Sample\ (g)}\ x\ 100 \quad (1)$$

2.4 Statistical Analysis

All experiments were performed in triplicate (n=3) to ensure statistical reproducibility and to determine the standard deviation. Results are presented as mean ± standard deviation.

Differences between extraction methods were evaluated using an independent sample t-test with significance level $p < 0.05$.

3 Result and Discussion

The average yield of *Sterculia quadrifida* R.Br seed oil obtained by the Soxhlet method and maceration with hexane solvent, is presented in Table 1.

Table 1. Mean oil yield of *S. quadrifida* seeds obtained by different extraction methods (%)

Method	Replicate 1 (%)	Replicate 2 (%)	Replicate 3 (%)	Mean ± SD
Soxhlet-Rotary Evaporation	30.62	31.62	29.64	30.65 ±1.00
Maceration-Distilation	31.17	30.19	31.49	30.95±0.68

Note: $p = 0.668$ (not statistically significant at $\alpha = 0.05$).

The oil yield obtained using Soxhlet-rotary evaporation was 30.65 ± 1.00%, while maceration-distillation produced 30.95 ± 0.68%. Statistical analysis showed no significant difference between the two methods ($p = 0.668$). A comparative illustration of the oil yield results between the two extraction and evaporation methods can be seen in Figure 3.

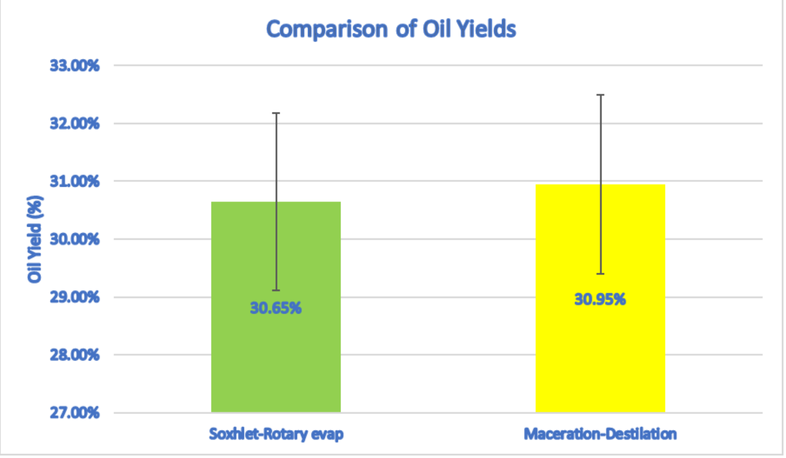

Fig. 3. Comparison of Oil Extraction Yields Across Different Solvent Recovery Techniques.

The absence of significant differences suggests that both extraction systems achieved comparable mass transfer equilibrium. Although Soxhlet extraction operates at higher temperature with continuous solvent cycling, the shorter extraction duration may limit solvent penetration into deeper cellular structures. In contrast, maceration provides prolonged solvent contact at lower temperature, allowing gradual diffusion and near-equilibrium extraction. Oil yield variation may also be influenced by several factors, including growing location, plant variety, processing duration, and pre-treatment condition [10]. Additionally, Solvent polarity also affects extraction efficiency and extract composition [11].

Soxhlet extraction operates at higher temperature with continuous extraction, enhancing oil release [12], but shorter duration may limit solvent penetration. Maceration allows longer solvent contact time at lower temperature, enabling gradual diffusion toward thermodynamic equilibrium [13].

The Soxhlet-rotary evaporation method yielded 30.65%, while maceration-distillation yielded 30.95%, with only a 0.31% difference. This indicates similar extraction performance. The very small difference in oil yield indicates that solvent–matrix interaction time and solvent removal efficiency may compensate for differences in extraction temperature. This finding suggests that extraction performance should be evaluated as an integrated process rather than as isolated unit operations.

Furthermore, *Sterculia quadrifida* R.Br seed oil obtained with hexane solvent, either by the Soxhlet method or maceration, produces a golden yellow oil (Figure 4). The golden yellow color of *Sterculia quadrifida* R.Br seed oil produced may be due to the presence of carotenoid and lutein pigments, which are soluble in vegetable oil [14].

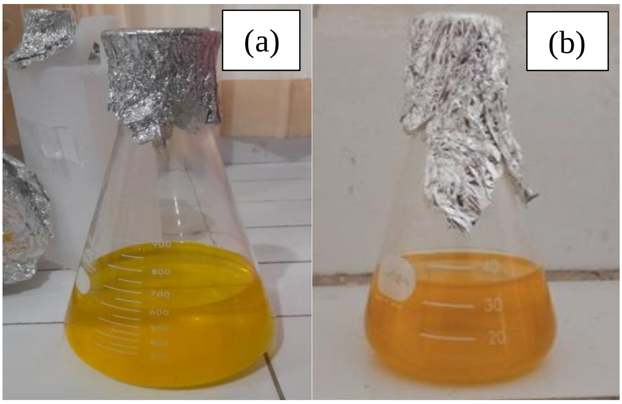

Fig. 4. *Sterculia quadrifida* R.Br Seed Oil Obtained from (a). Soxhlet-Rotary evaporator method, (b). Maceration-Distillation method.

Differences in solvent removal conditions may also influence oil recovery. Rotary evaporation operates under reduced pressure, whereas distillation occurs at atmospheric pressure with longer heating duration, potentially improving solvent removal [15]. From a practical perspective, the comparable efficiency of both systems provides flexibility for industrial application. Method selection may therefore depend on operational considerations such as energy consumption, processing time, equipment availability, and production scale.

This study evaluated oil yield only. Oil quality parameters such as fatty acid composition, oxidative stability, and bioactive compound retention were not assessed. These factors may differ between extraction systems and should be investigated in future studies.

4 Conclusion

Extraction method and solvent evaporation technique influence the oil yield of *Sterculia quadrifida* R.Br seeds. Maceration–distillation produced 30.95 ± 0.68%, while Soxhlet–rotary evaporation produced 30.65 ± 1.00%, with no statistically significant difference.

These results demonstrate that different combinations of extraction and solvent removal techniques can achieve similar oil recovery efficiency. Process selection may therefore be guided by operational efficiency rather than yield alone. The findings provide a foundation for further optimization and scale-up of oil extraction from *Sterculia quadrifida* R.Br seeds.

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