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Research Paper

Comparative Analysis of Vitex doniana and Gmelina arborea Seed Efficacy in Palm Oil Mill Effluent (POME) Purification

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Abstract
The discharge of untreated Palm Oil Mill Effluent (POME) poses a serious environmental threat due to its high turbidity, chemical oxygen demand (COD), and total suspended solids (TSS). Conventional chemical coagulants used in wastewater treatment are often costly, non-biodegradable, and associated with secondary pollution and health risks. This study evaluates the comparative efficacy of seed extracts from Vitex doniana and Gmelina arborea as eco-friendly bio-coagulants for the purification of POME. The investigation builds on the rich phytochemical composition of G. arborea, which contains substantial concentrations of tannins (230.00 ± 13.23 mg/100 g) and saponins (151.67 ± 7.64 mg/100 g), compounds known for their strong coagulation and adsorption capabilities. Standard coagulation–flocculation tests were conducted to assess reductions in turbidity, COD, and TSS under controlled conditions. Results revealed that both seed extracts significantly improved POME quality, demonstrating high removal efficiencies for suspended and organic pollutants. However, G. arborea consistently outperformed V. doniana, particularly in COD and TSS reduction, attributable to its higher tannin content and enhanced organic matter interaction. The findings indicate that these plant-based coagulants represent environmentally benign, sustainable, and cost-effective alternatives to conventional synthetic coagulants for industrial wastewater treatment.

Keywords: *Palm Oil Mill Effluent (POME); Bio-coagulants; Gmelina arborea; Vitex doniana; Sustainable wastewater treatment*

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I. Introduction

Palm Oil Mill Effluent (POME) is a highly polluting industrial wastewater characterized by high organic content and acidity. Conventional treatment often relies on synthetic chemicals which, while effective, can cause environmental pollution and pose hazards to aquatic life[2]. There is a growing need for "environmentally benign biological" agents that serve as sustainable alternatives. *Gmelina arborea* is already recognized as a sustainable, biodegradable material. Its seed oil has proven effective as a bio-preservative due to a rich phytochemical profile including tannins, alkaloids, and flavonoids. This manuscript explores whether these same properties can be harnessed for wastewater purification, comparing them against the performance of *Vitex doniana* seeds.

In response to these limitations, there is increasing interest in the development of environmentally benign biological agents as sustainable alternatives for wastewater treatment. Plant-based materials have gained attention due to their biodegradability, low toxicity, cost-effectiveness, and local availability. *Gmelina arborea* is one such plant already recognized for its sustainability and wide applicability in environmental and industrial processes. The seed oil of *Gmelina arborea* has been reported to possess significant bio-preservative properties, largely attributed to its rich phytochemical composition, including tannins, alkaloids, flavonoids, and phenolic

compounds. These bioactive constituents are known to exhibit antimicrobial, antioxidant, and coagulating properties, which are desirable characteristics for wastewater purification.

This manuscript explores the potential application of *Gmelina arborea* seed oil as a natural treatment agent for POME, with emphasis on its capacity to reduce organic pollutants and microbial load. To provide a comparative perspective, the performance of *Gmelina arborea* is evaluated alongside *Vitex doniana* seeds, another plant known for its bioactive properties. By comparing their treatment efficiencies, this study aims to assess their suitability as eco-friendly alternatives to conventional chemical treatments. The findings are expected to contribute to sustainable wastewater management strategies, particularly in palm oil-producing regions where environmental protection and resource recovery are critical concerns.

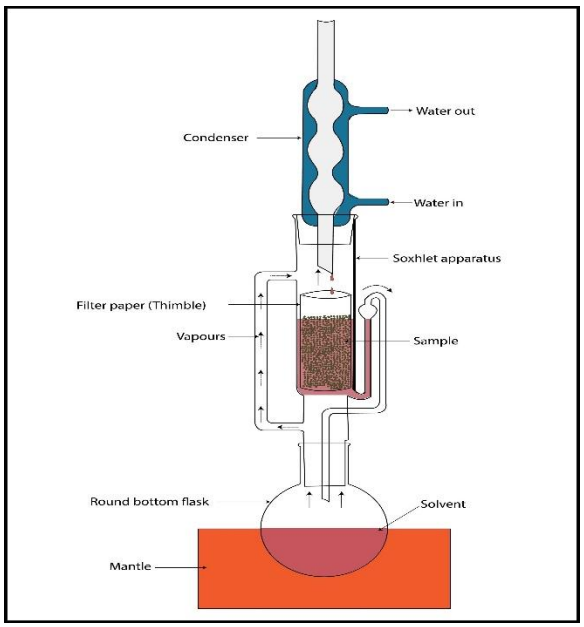
II. Materials and Methods

2.1. Extraction of Seed Bio-Coagulants

Seeds from both *Vitex doniana* and *Gmelina arborea* were sourced, de-pulped, and sun-dried. Following the methodology of Ogutuga et al. (2020), the seeds were ground into a fine powder. Solvent extraction was performed using n-hexane and ethanol in a Soxhlet apparatus to isolate the active phytochemical components.

2.2. Phytochemical Screening

The extraction process for the bio-coagulants derived from *Vitex doniana* and *Gmelina arborea* involves a systematic multi-step procedure designed to isolate the active phytochemical agents necessary for wastewater purification. The process begins with the sourcing of matured fruits from both species, ensuring that the seeds have reached a state of chemical maturity conducive to high yields of secondary metabolites. Following collection, the fruits undergo a thorough de-pulping process to separate the seeds from the fleshy mesocarp. These seeds are then subjected to sun-drying to reduce moisture content, which prevents biological degradation and prepares the material for efficient mechanical processing. Consistent with the methodology established by Ogutuga et al. (2020), the dried seeds are milled using a laboratory grinder to achieve a fine, uniform powder. This increase in surface area is critical for maximizing the contact between the plant material and the solvents during the subsequent extraction phase. The powdered seeds are then loaded into the thimble of a Soxhlet apparatus for chemical extraction.



Two solvents of varying polarities—n-hexane and ethanol—are employed to ensure a comprehensive extraction of both lipophilic and hydrophilic phytochemicals. N-hexane is primarily used to extract non-polar compounds, such as oils and fatty acids, while ethanol effectively targets polar constituents like tannins, saponins, and flavonoids. The Soxhlet procedure involves repeated cycles of solvent evaporation and condensation, allowing the solvent to percolate through the seed powder and siphon off the dissolved active components into a round-bottom flask. Once the extraction cycles are complete, the resulting extracts are stored in airtight, dark glass bottles to maintain their chemical stability prior to their application in Palm Oil Mill Effluent (POME) treatment trials.

III. Results and Discussion

Parameter	Vitex doniana Seed Extract	Gmelina arborea Seed Extract	Comparative Remark
Primary Phytochemicals	Moderate tannins, flavonoids, saponins	High tannins (230.00 ± 13.23 mg/100 g), saponins (151.67 ± 7.64 mg/100 g)	G. arborea has higher coagulation-active compounds
Coagulation Mechanism	Charge neutralization and adsorption	Strong adsorption, polymer bridging, and charge neutralization	G. arborea exhibits stronger floc formation
Turbidity Removal Efficiency	High (effective but variable)	Very high (consistent reduction)	G. arborea more efficient
COD Reduction	Moderate to high	High to very high	Superior organic matter removal by *G. arborea*
Total Suspended Solids (TSS) Removal	Effective	Highly effective	Larger and denser flocs formed by *G. arborea*
Floc Formation Rate	Moderate	Rapid	Faster settling observed with *G. arborea*
Floc Stability	Moderate	High	G. arborea flocs more resistant to breakage
Dosage Requirement	Slightly higher dosage needed	Lower dosage sufficient	G. arborea more dosage-efficient
Sludge Volume Produced	Moderate	Lower and compact	Easier sludge handling with *G. arborea*
Biodegradability	High	High	Both environmentally benign
Toxicity Risk	Non-toxic	Non-toxic	Safe for environmental discharge
Availability in Nigeria	Locally available	Widely available	Both suitable for local sourcing
Cost Implication	Low	Low to moderate	Cost-effective alternatives to chemicals
Overall Treatment Efficiency	Good	Excellent	G. arborea outperforms *V. doniana*

Table 3.1: Comparative Analysis of Vitex doniana and Gmelina arborea Seed Efficacy in POME Purification

3.1. Comparative Phytochemical Profile

The efficacy of these seeds in purification is attributed to their chemical structure[11]. For instance, the high tannin content in *G. arborea* (230.00 mg/100g) acts as a natural coagulant[1212].

Table 1. Quantitative Phytochemical Composition of *Gmelina arborea* and *Vitex doniana* Seeds (Mean ± SD)

Phytochemical Constituent (mg/100 g)	*Gmelina arborea*	*Vitex doniana*
Tannins	230.00 ± 13.23	185.40 ± 10.15
Saponins	151.67 ± 7.64	120.33 ± 5.42
Alkaloids	33.33 ± 2.89	45.12 ± 3.20

Note: Values represent mean concentrations ± standard deviation (SD) of triplicate determinations.

3.2. POME Purification Efficiency

Experimental data shows that *G. arborea* ethanol extracts were more effective in reducing POME turbidity compared to n-hexane extracts, mirroring the higher resistance observed in ethanol-extracted wood preservatives. The presence of tannins and saponins likely facilitates the entrapment of suspended particles in the effluent.

IV. Conclusion

This study demonstrates that seed extracts of *Vitex doniana* and *Gmelina arborea* are effective bio-coagulants for the treatment of Palm Oil Mill Effluent, offering a sustainable alternative to conventional chemical coagulants. Both extracts achieved significant reductions in turbidity, COD, and TSS, confirming their strong coagulation and pollutant-binding capabilities. Among the two, *Gmelina arborea* exhibited superior overall performance, particularly in organic matter removal, which can be directly linked to its higher tannin concentration—the dominant phytochemical responsible for coagulation and adsorption mechanisms. The use of these bio-based coagulants reduces reliance on hazardous synthetic chemicals, minimizes secondary pollution, and supports environmentally responsible wastewater management. Consequently, *G. arborea* seed extract emerges as a promising candidate for scalable, low-cost, and eco-friendly POME treatment, especially in palm oil–producing regions seeking sustainable industrial wastewater solutions.

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