Enhancement of Scalp Sebum Reduction in Kaffir Lime Shampoo Using Lignin Extracted from Sugarcane Bagasse

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Abstract

Excessive scalp oiliness arises from sebaceous gland hyperactivity, resulting in excess sebum, follicular blockage, and microbial proliferation. Therefore, effective and sustainable agents for sebum regulation and microbial inhibition are required. This study aimed to investigate the potential of lignin extracted from sugarcane bagasse as a natural material for enhancing scalp sebum reduction and to evaluate its antibacterial activity against scalp-associated bacteria. Lignin was extracted from sugarcane bagasse via the organosolv method and subsequently characterized for its physicochemical properties. The extraction yield was 3.44 ± 0.12, and the average particle size was approximately 777.2 nm. Moreover, the oil adsorption capacity of lignin was evaluated in vitro by quantitatively measuring the amount of oil absorbed and comparing it with a control sample. The results demonstrated that lignin extract exhibited a high oil adsorption capacity, with an average value of 3.127 ± 0.167 g of oil per gram of lignin, which was significantly higher than that of the control. In addition, lignin showed antibacterial activity, with the minimum inhibitory concentration (MIC) values of approximately 5 mg/mL against *Staphylococcus aureus*, *Staphylococcus epidermidis*, and *Pseudomonas aeruginosa*. The minimum bactericidal concentration (MBC) against *S. aureus* was approximately 10 mg/mL, whereas lignin concentrations greater than 10 mg/mL were required to achieve bactericidal activity against *S. epidermidis* and *P. aeruginosa*. This study demonstrates that sugarcane bagasse–derived lignin is a promising natural active ingredient for hair care applications, providing sebum-regulating and antibacterial effects while promoting sustainable agricultural waste valorization.

Introduction

Excessive scalp oiliness leads to sebum accumulation, greasy hair, and microbial growth. While many oil-control shampoos rely on synthetic ingredients that may cause irritation and environmental concerns, kaffir lime shampoo offers a natural alternative but has limited sebum-control efficacy. Sugarcane bagasse, an abundant agricultural by-product from the sugar industry, mainly consists of cellulose, hemicellulose, and lignin, as shown in **Figure 2** Among these components, lignin is a natural aromatic polymer with hydrophobic and porous structures and phenolic functional groups that contribute to oil adsorption and antibacterial activity. In particular, organosolv lignin, obtained through an organic solvent extraction process, provides high purity and preserves important functional groups. These characteristics make organosolv lignin a promising bio-based material for enhancing sebum control and antimicrobial performance in shampoo formulations.

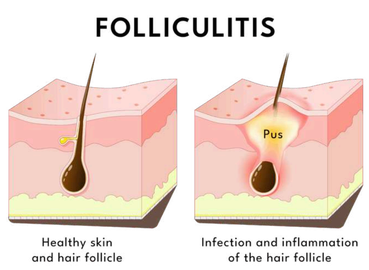


Figure 1. Follicular blockage

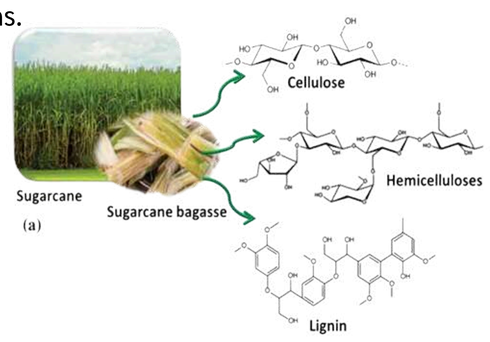


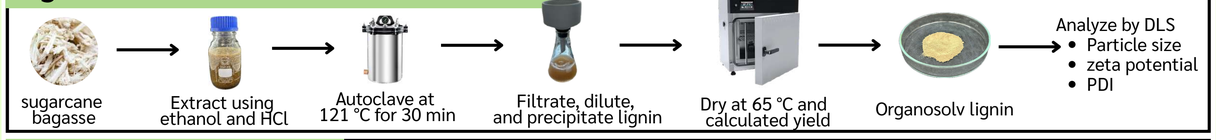
Figure 2. The sugarcane, the sugarcane bagasse, and its principal components

Objectives

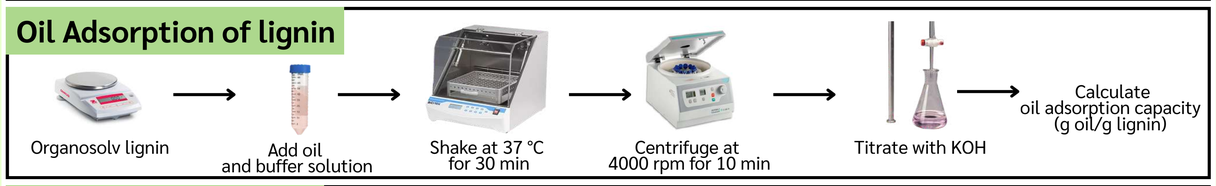
1. To extract and characterize lignin from sugarcane bagasse as a potential natural biomaterial
2. To evaluate the functional properties of lignin, including oil adsorption capacity and antibacterial activity against scalp-associated bacteria
3. To explore the application of lignin as a sustainable active ingredient for enhancing sebum control in kaffir lime shampoo formulations

Methodology

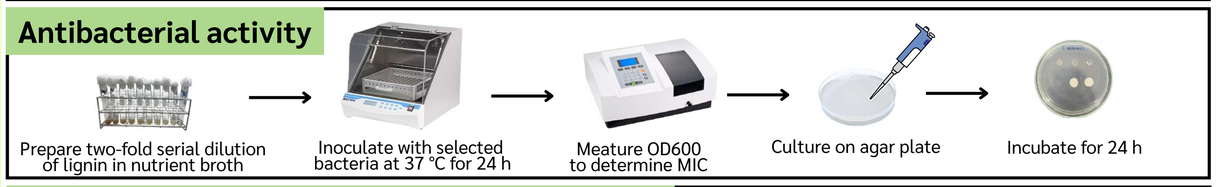
Lignin extraction and characterization



Oil Adsorption of lignin



Antibacterial activity



Shampoo Incorporation with organosolv lignin



Acknowledgement

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Results and discussions

Organosolv lignin and characterization

Organosolv lignin was successfully extracted from sugarcane bagasse with a yield of 3.44 % (Table 1). **Figure 4** presents a light yellow fine lignin powder. Particle size of lignin analysis showed an average size of 777.2 nm (as shown in Table 1), indicating submicron particles suitable for dispersion in formulations. The zeta potential value of –32.5 mV suggested good colloidal stability, while the moderate polydispersity index reflected some degree of particle aggregation.

Table 1. Yield and characteristic of organosolv lignin

Organosolv lignin	Content
Yield (%)	3.44±0.12
Particle Size Distribution (nm)	777.20±87.45
Zeta Potential (mV)	-32.5±0.40
Polydispersity Index	0.507±0.069



Figure 4. Organosolv lignin

Oil adsorption of lignin

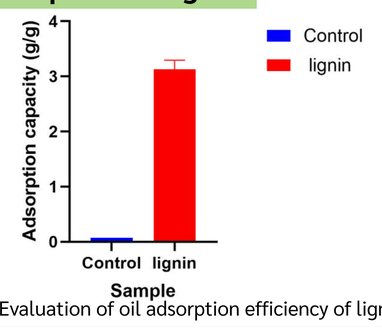


Figure 5. Evaluation of oil adsorption efficiency of lignin

In terms of oil adsorption, lignin exhibited a high adsorption capacity of 3.127 ± 0.167 g oil/g lignin, significantly higher than the control (Figure 5). This result demonstrates that lignin can retain more than three times its own weight in oil. The strong adsorption performance is likely attributed to its hydrophobic and porous structure. These findings indicate its potential application as an effective sebum-controlling agent.

Antibacterial activity

Organosolv lignin showed a minimum inhibitory concentration (MIC) of 5 mg/mL against *S. aureus*, *S. epidermidis*, and *P. aeruginosa*. Bactericidal activity (MBC) was observed at 10 mg/mL for *S. aureus*, while higher concentrations were required for the other strains. The stronger effect against Gram-positive bacteria may be associated with the interaction of phenolic functional groups in lignin with bacterial cell walls. These results confirm the multifunctional antimicrobial potential of lignin.

Table 2. The minimum inhibitory concentration (MIC) of organosolv lignin against selected bacterial

The selected bacterial strain	MIC (mg/mL)
S. aureus	5
S. epidermidis	5
P. aeruginosa	5

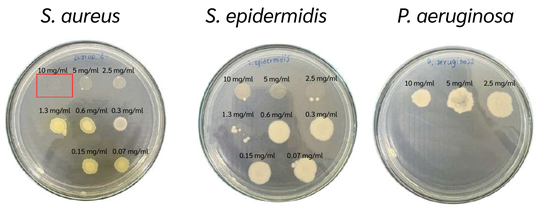


Figure 6. the minimum bactericidal concentration (MBC) of organosolv lignin against the selected bacterial strains

Shampoo Incorporation with organosolv lignin

Figure 7 showed uniform dispersion after lignin incorporation, with no visible precipitation observed. A discoloration to a light brown color was observed.

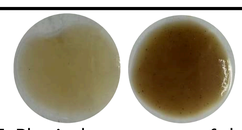


Figure 7. Physical appearance of shampoo before and after lignin incorporation

Conclusion

- Lignin was extracted from sugarcane bagasse by the organosolv method, yielding 3.44±0.12% with an average particle size of 777.2±87.5 nm and good colloidal stability.
- Organosolv lignin showed an adsorption capacity of 3.127 ± 0.167 g oil/g lignin, indicating strong oil-binding ability suitable for sebum control application.
- Organosolv lignin exhibited antibacterial activity against *S. aureus*, while higher concentrations (>10 mg/mL) were required for *S. epidermidis* and *P. aeruginosa*.
- The lignin-incorporated shampoo maintained uniform dispersion without visible precipitation, indicating acceptable formulation stability.

Referencenes

- Nakason, K., Chukaew, P., Thongpanich, Y., et al. (2024). Sugarcane leaf-derived organosolv lignin as antibacterial and antioxidant agents. *Cleaner Materials*, 100280.
- Tolba, R., Wu, G., & Chen, A. Adsorption of dietary oils onto lignin for pharmaceutical applications.