Utilization of Lignin Extracted from Longan Peel as an Ingredient in Peel-off Acne Treatment Gel

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ABSTRACT

This research aimed to utilize lignin extracted from longan (*Dimocarpus longan*) peel, an abundant agricultural waste in northern Thailand, as an ingredient in a peel-off acne treatment gel formulation. Lignin was extracted from longan peel using the organosolv method, employing 70% (v/v) ethanol as the solvent and hydrochloric acid as a catalyst. Following lignin extraction and precipitation, the lignin yield obtained ranged from 1.50% to 4.98%. The physicochemical properties of the extracted lignin were characterized. FTIR confirmed the characteristic functional groups of lignin. DLS analysis revealed particle sizes ranging from 615.1 to 1484 nm with zeta potentials between −33.3 and −35.0 mV, indicating good colloidal stability. Antibacterial activity was evaluated using MIC, MBC, and disc diffusion assays against *S.aureus*, *S.epidermidis*, and *P.aeruginosa*. The results demonstrated that longan peel–derived lignin exhibited strong antibacterial activity, with MIC values ranging from 0.31 to 1.25 mg/mL and an MBC of 10 mg/mL against all tested strains. Furthermore, the extracted lignin was incorporated into a peel-off acne treatment gel formulation using carboxymethyl cellulose and polyvinyl alcohol as the base components. The formulated peel-off gel demonstrated stronger antibacterial activity than commercial products. The characteristics of the gel showed no significant changes in color, homogeneity, or external appearance during storage at room temperature for 7 days. These findings indicated that lignin derived from longan peel exhibits antibacterial properties and represents a promising natural and sustainable ingredient for skincare applications, while also contributing to the value-added utilization of agricultural waste.

INTRODUCTION

Longan peel is an abundant agricultural by-product rich in lignocellulosic components, including cellulose, hemicellulose, and lignin. Among these components, lignin is a natural aromatic polymer known for its various biological activities such as antimicrobial, antioxidant, and anti-inflammatory properties. Organosolv extraction is a promising method for lignin recovery because it produces sulfur-free lignin with relatively low molecular weight and high purity. Acne vulgaris is a common skin disorder associated with follicular blockage, excessive sebum production, and bacterial proliferation, particularly *Staphylococcus aureus*, *Staphylococcus epidermidis*, and *Pseudomonas aeruginosa*. Although commercial acne patches are widely used, they often have limitations such as poor adhesion and incomplete coverage of irregular lesions. Therefore, this study aims to develop a peel-off acne treatment gel containing organosolv lignin extracted from longan peel to enhance antibacterial activity and improve contact with acne lesions.

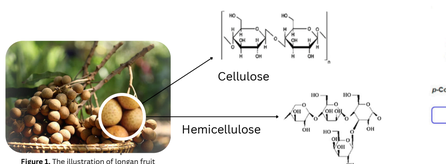


Figure 1. The illustration of longan fruit

The lignocelluloic composition in longan peel

- Cellulose 45.5 %
- Hemicellulose 2.1 %
- Lignin 18.6 %

(Wanlapa et al., 2015)

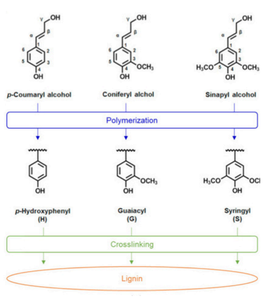


Figure 2. The percursors for the structural units in the lignin backbone (Saadan et al., 2024)

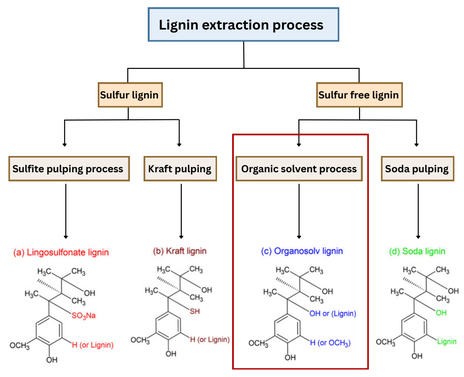
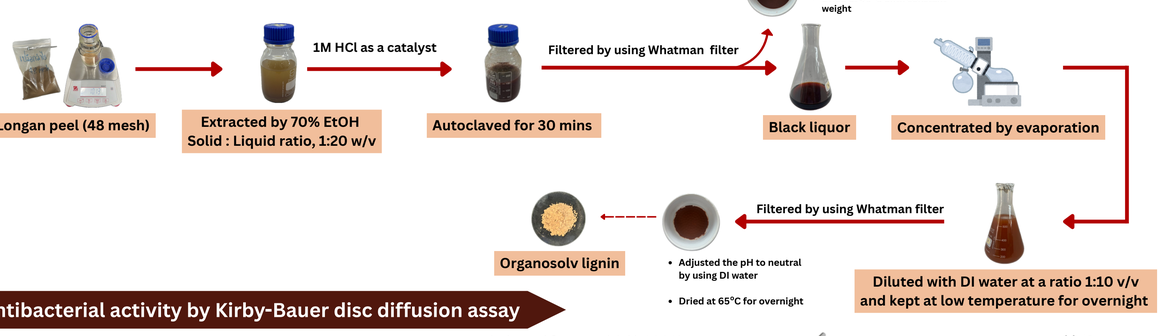


Figure 3. Chemical structures of some types of lignin obtained from various extraction and purification processes (Saadan et al., 2024; Wanlipakorn, 2023)

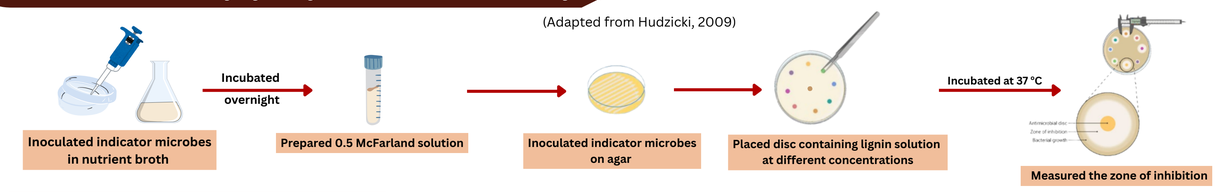
METHODS

• Extraction of organosolv lignin from longan peel



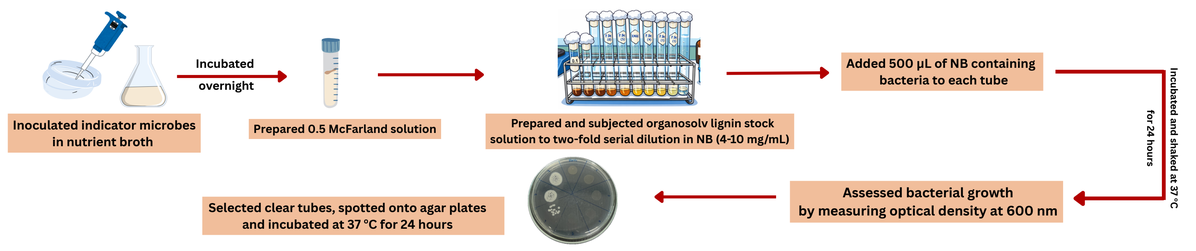
• Antibacterial activity by Kirby-Bauer disc diffusion assay

(Adapted from Hudzicki, 2009)



• Antibacterial activity (MIC and MBC)

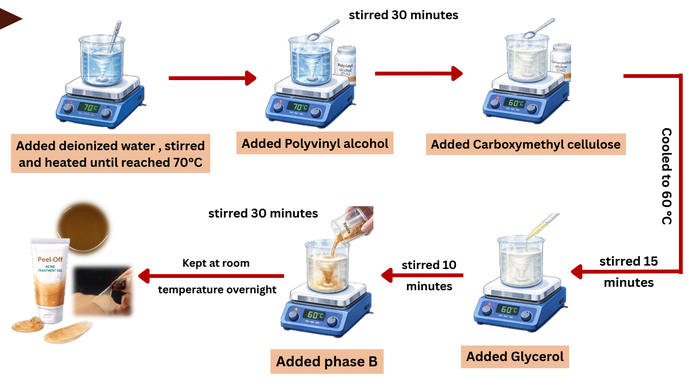
(Adapted from Yun et al., 2021)



• Peel-off acne treatment gel formulation

Table 1. Peel-Off Acne Treatment Gel formulation

Phase	Ingredients	Functions	Content (% w/w) F0	Content (% w/w) F1
A	Polyvinyl alcohol	Flexibility and Strength	7.00	7.00
	Carboxymethyl cellulose	Gel Matrix, Viscosity and Stability	1.50	1.50
	Glycerol	Humectant, Plasticizer	3.00	3.00
	Deionized water	Solvent	78.10	77.97
B	Citric acid	Crosslinking agent	0.40	0.40
	Organosolv lignin	Active ingrediant, Antimicrobial properties	-	0.13
	Deionized water	Solvent	10.0	10.0
	Total		100.00	100.00



RESULTS AND DISCUSSIONS

Characteristics of organosolv lignin

The organosolv lignin was obtained as a yellow-brown fine powder (Figure 4.) with a yield of 4.42%. The lignin exhibited good colloidal stability, as indicated by a zeta potential value of −34.17 mV, suggesting sufficient electrostatic repulsion between particles. The purity of the extracted lignin, expressed as total lignin content, was 75.55%, indicating effective removal of non-lignin components during the extraction process. In addition, the organosolv lignin showed a relatively homogeneous particle size distribution, with a polydispersity index (PDI) of 0.574, as shown in Table 2., suggesting moderate uniformity of the lignin particles.

Table 2. Physicochemical Characteristics of organosolv lignin

Organosolv lignin	Content
% Yeild of lignin (%)	4.42 ± 0.30
% Total lignin (%)	75.55 ± 0.20
Particle Size Distribution (nm)	878.03 ± 78.78
Zeta Potential (mV)	-34.17 ± 8.68
Polydispersity Index	0.574 ± 0.169



Figure 4. Organosolv lignin from longan peel

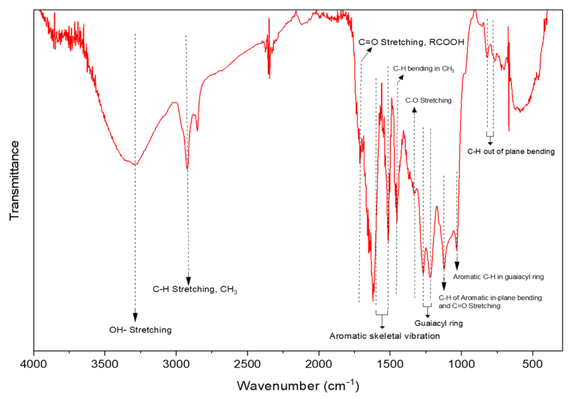


Figure 5. Fourier transform infrared (FTIR) spectra of longan peel extract

Organosolv lignin exhibited antibacterial activity against all tested bacteria in a concentration-dependent manner. The inhibition zones increased slightly as lignin concentration increased from 4 to 10 mg/mL (Table 3.). *S. epidermidis* showed the largest inhibition zones (10.31–11.18 mm), followed by *S. aureus* (8.75–10.23 mm), indicating higher susceptibility of Gram-positive bacteria. In contrast, *P. aeruginosa* showed inhibition only at higher concentrations (8–10 mg/mL), which may be attributed to the protective outer membrane typical of Gram-negative bacteria.

Table 3. Antibacterial activity of organosolv lignin against test microorganisms determined by the Kirby-Bauer disc diffusion method

Lignin concentration (mg/mL)	Diameter of the inhibition zone (mm)		
	S. aureus	*S. epidermidis*	*P. aeruginosa*
4	8.75 ± 0.20	10.31 ± 0.93	-
6	8.90 ± 0.65	10.61 ± 1.03	-
8	10.16 ± 0.24	10.48 ± 0.87	8.56 ± 0.36
10	10.23 ± 0.62	11.18 ± 0.69	10.38 ± 0.19

Antibacterial activity of organosolv lignin

Lignin exhibited antibacterial activity against *S. aureus* with a MIC of 1.25 mg/mL and an MBC of 10 mg/mL, where no visible bacterial colonies were observed on the agar plate (Figure 6.). For *S. epidermidis*, lignin showed a MIC of 0.31 mg/mL and an MBC of 10 mg/mL. The lower MIC value compared with S. aureus indicates that S. epidermidis was more susceptible to lignin. this difference may be associated with variations in cell wall structure and physiological characteristics among Gram-positive bacteria. Lignin also inhibited thje growth of *P. aeruginosa*, with a MIC of 0.31 mg/mL and an MBC of 10 mg/ mL. Despite being a Gram-negative bacterium, which typically possesses an outer membrane that acts as a barrier to antimicrobial agents, lignin was still able to inhibit bacterial growth at relatively low concentrations. This suggests that lignin may interact with bacterial cell membranes nor interfere with cellular functions.

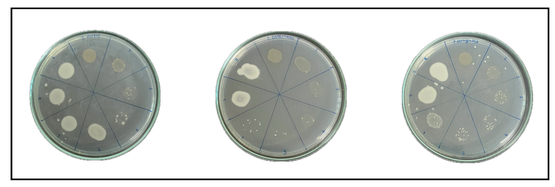


Figure 6. The MIC and MBC of lignin against (A) *S. aureus* (B) *S. epidermidis* (C) *P. aeruginosa*

Table 4. Antibacterial activity of peel-off acne treatment gel

Sample	Diameter of the inhibition zone (mm)		
	S. aureus	*S. epidermidis*	*P. aeruginosa*
F0 (Control)	20.75 ± 0.35	26.18 ± 0.29	21.26 ± 0.68
F1	22.44 ± 0.89	27.54 ± 1.12	23.99 ± 1.49
Commercial product	15.94 ± 1.53	26.73 ± 0.54	23.32 ± 0.69

After 24 h incubation, formulation F1 showed the strongest antibacterial activity against all tested bacteria (Table 4.). The inhibition zones were larger than those of the control (F0) and comparable to or higher than the commercial product, suggesting that lignin incorporation enhanced the antibacterial performance of the peel-off gel.

Preparation of peel-off acne treatment gel

Both formulations were successfully prepared (Figure 7.) as homogeneous semi-solid gels with a typical odor and stable pH values (4–5) throughout 7 days of storage, indicating suitable properties for topical application. The control formulation (F0) appeared transparent, whereas the lignin-containing formulation (F1) showed a clear brown color, which is attributed to the natural pigment of lignin. No phase separation or changes in homogeneity were observed, demonstrating good physical stability of the formulations during storage. Furthermore, F1 exhibited a shorter drying time (3.37–3.45 min) compared with F0 (4.16–4.23 min), suggesting that the incorporation of lignin may enhance the film-forming behavior and drying efficiency of the peel-off gel.

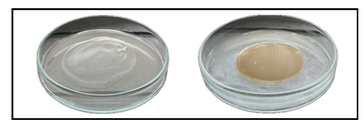


Figure 7. The formulation of peel-off acne treatment gel (A) Control (B) Lignin-containing formulation

CONCLUSION

- Organosolv lignin has a yield of 4.42 ± 0.30%, an average particle size of 878.03 ± 78.78 nm and demonstrated good colloidal stability. The purity of the extracted lignin was approximately 75.55 ± 0.20%.
- The MIC values were 0.31 mg/mL for *S. epidermidis* and *P. aeruginosa* and 1.25 mg/mL for *S. aureus*, whereas the MBC was 10 mg/mL for all tested bacteria.
- The formulated peel-off gel demonstrated stronger antibacterial activity than commercial products and no significant changes in external appearance during storage at room temperature for 7 days.

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