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ANTIBACTERIAL ACTIVITY OF Leea indica LEAF EXTRACT AGAINST Escherichia coli ATCC 25922

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Abstract
Background: Leea indica, a large herbaceous plant traditionally used to treat diarrhea, has been studied for its medicinal potential. However, research on the antibacterial activity of its extract against Escherichia coli has not yet been widely reported.
Objective: This research was conducted to assess the antibacterial potential of Leea indica leaf extract against E. coli ATCC 25922 and to identify its phytochemical profile.
Methods: Leaves of Leea indica were subjected to maceration using 96% ethanol, followed by solvent removal to obtain a crude extract. Antibacterial activity was evaluated through the agar well diffusion technique using extract concentrations of 20%, 10%, and 5%. The diameters of inhibition zones were recorded to assess antibacterial strength. Phytochemical screening was carried out qualitatively to identify secondary metabolite compounds.
Results: The extract at a concentration of 20% showed the widest inhibition zone, measuring 27.26 mm, indicating very strong antibacterial activity. Phytochemical tests revealed the presence of flavonoids, alkaloids, tannins, phenolic compounds, steroids, and saponins.
Conclusions: The findings indicate that Leea indica leaf extract has significant antibacterial activity against E. coli ATCC 25922. The detected secondary metabolites may contribute to its antibacterial effect and support its traditional application in diarrhea management.

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INTRODUCTION

Diarrhea is a disease commonly caused by infection with microorganisms. It is defined as the passage of abnormally loose or liquid stools, occurring three or more times within a 24-hour period (1). Among the causative agents, Escherichia coli is one of the main pathogenic bacteria responsible for diarrhea. E. coli is classified as a Gram-negative bacterium that naturally inhabits the digestive systems of humans and animals, where harmless strains cintribute to normal digestive functions. However, pathogenic strains of *E. coli* can invade the intestinal mucosa, attach to epithelial cells, and trigger an inflammatory response that may cause bleeding (2).

Diarrheal diseases cause over 1 million deaths annually, with children under 5 years being the most affected group. In Indonesia, the occurrence of diarrhea in children below five years of age remains persistently elevated, as indicated by national survey data showing prevalence rates ranging from 11% to 12,3% in recent years Mortality rates in Indonesian children aged 12–59 months due to diarrhea are reported at 4.55% .Regional data show significant variation, with some provinces like South Kalimantan reaching nearly 20% prevalence, while Bali reports around 10.5%(1).

Treatment of gastrointestinal infections caused by *Escherichia coli* primarily focuses on supportive care and maintaining proper hydration status. Most patients are treated with drugs from various therapeutic groups, such as antimotility drugs, adsorbent agents, antisecretory medications, antibiotics, and preparations containing beneficial intestinal microorganisms (3). However, inappropriate or excessive use of antibiotics can lead to the development of resistance (4). One of the most important factors influencing bacterial infections and antibiotic resistance is the ability of *E. coli* to form biofilms, which enhances bacterial survival and makes treatment more difficult. Biofilm formation can increase resistance to antimicrobial therapy by up to 100–1000 times (5).

Based on these considerations, researchers are interested in utilizing natural materials as alternative antibiotics. The use of medicinal plants as an alternative treatment for bacterial infections offers several advantages, including fewer side effects compared to synthetic drugs, wide availability, and lower cost. *Leea indica* (locally known as leaf girang-girang) is one of the potential plants that can be developed as an alternative treatment for bacterial infections. This plant is known to have antibacterial potential by inhibiting bacterial growth. Previous research demonstrated that *L. indica* leaf the extract demonstrated inhibitory effects on the growth of Staphylococcus aureus and Salmonella typhi (6). The antimicrobial properties of this plant are associated with the presence of biologically active constituents. Phytochemical studies have reported that *L. indica* contains several bioactive metabolites, including alkaloids, carotenoids, coumarins, dihydrochalcones, fatty acids, polyphenols, flavonoids, tannins, steroids, glycosides, terpenoids, and saponins (7). Scientific studies that specifically assess the antibacterial properties of Leea indica leaf extract toward *Escherichia coli* ATCC 25922 remain limited, particularly in the context of diarrhea-causing bacteria. This lack of empirical evidence creates a knowledge gap regarding the possibility of Leea indica being developed as a scientifically supported source of natural antibacterial compounds.

MATERIALS AND METHODS

Material

Materials used in the study are leaf girang-girang (*L.indica*) obtained from JL. Palapa IV, Sesetan, South Denpasar, Denpasar City, Bali 80223, while material chemicals used is Aquades , Ethanol 96% (E Merck), Nutrient Agar (Oxoid), Hydrochloric acid (HCl) Merck, magnesium (Mg) , glacial acetic acid, concentrated sulfuric acid (H_2SO_4) Merck 1.00731.2500, ammonia (NH_3) Merck 105432, Dragendorf Merck, 2,2, Ciprofroxacin 1%

Method

This study employed both quantitative and qualitative experimental methods. *Leea indica leaves* (1 kg) were air-dried at ambient for 3 days and then ground into powder using a blender (8). A total of 100 g of the powdered leaves was subjected to maceration in 1000 mL of 96 percent ethanol at a ratio of 1:10 (w/v) (9). The solution was stored in a sealed container at room temperature for 48 hours, after which it was filtered through Whatman filter paper with a pore diameter of 2.5 µm. The resulting filtrate was then concentrated by means of a rotary evaporator to produce the crude extract material of L. indica leaves (10).

The antibacterial effect of Leea indica leaf crude extract on E. coli ATCC 25922 was evaluated using the well agar well diffusion technique (diffusion method). A total of 15 mL of Nutrient Agar (NA) was dispensed into sterile Petri plates and left to solidify. After the medium had solidified, a suspension of *E. coli* ATCC 25922 was applied to the agar surface using a sterile cotton swab. Agar wells measuring 5 mm in diameter were subsequently prepared. Each well received 20 µL of the leaf extract at different concentrations (5%, 10%, 15%, and 20% v/v), along with positive and negative controls. The plates were maintained under incubation at 37 °C for 24 hours. Antibacterial activity was demonstrated by the appearance of a clear inhibition zone around the wells. the inhibition zone diameters were measured in millimeters and classified as follows: ≥ 20 mm (very strong activity), 10–20 mm (strong activity), 5–10 mm (moderate activity), and < 5 mm (low or no activity) (11).

An extract volume of 2 mL sample was transferred into a test tube and allowed to extract with 5 mL of 2N HCl, then heated. After cooling, the solution was divided equally into three separate reaction tubes (1 mL each). Each tube was then treated with a different reagent. A positive reaction with Wagner's reagent produced a brown precipitate as a positive response. A positive result with Mayer's reagent was shown by the formation of a white precipitate, while Dragendorff's reagent produced an orange precipitate as a positive indication of alkaloids (11).

For the total flavonoid test, 2 g of the extract was subjected to heating for no more than 5 minutes, then 0.1 g of powdered magnesium (Mg) was added, followed by the dropwise addition of concentrated HCl. The color change was then observed using the Wilstätter method. The appearance of yellow, orange, or red coloration indicated a positive result for flavonoids (12). For steroids and terpenoids test, an aliquot of 2 mL extract was combined with the addition of 10 drops of glacial acetic acid (CH_3COOH) and 2 drops of concentrated sulfuric acid (H_2SO_4) as Liebermann–Burchard reagent. The solution was gently shaken and allowed to remain undisturbed for several minutes. Terpenoids are identified by the appearance of red or purple coloration, whereas steroids

are indicated by a green or blue coloration (13). Phenolic compounds was examined by reacting the extract with 5% $FeCl_3$ solution, where a change in a color change to green, red, purple, blue-black, or greenish-black indicated a positive result (14). Tannins were detected by boiling 1 mL of leaf extract with 10 mL of water for a duration of 5 minutes, followed by filtration, and the filtrate was then treated with 1% $FeCl_3$ solution; the appearance of a greenish-brown, blue, or greenish-black color confirmed the occurrence of tannins (15). Saponins were tested by placing 0.3 g of leaf extract in a test tube, followed by the addition of 10 mL distilled water and vigorous shaking for a period of 30 to 60 seconds; the formation of stable foam approximately 3 cm in height that persisted for more than 30 minutes was considered a positive result (16).

RESULTS AND DISCUSSION

Extraction of leaf samples yielded 2 g of crude extract. The antibacterial effect of the leaf extract on Escherichia coli ATCC 25922 is presented in Table 1. The suppressive effect of the extract on bacterial proliferation was demonstrated by the formation of a clear inhibition zone, as shown in Figure 1.

Table 1 Inhibitory zone of Leaf Extract on Escherichia coli ATCC 25922

Concentration Extract (w/v)	Inhibition Zone Diameter (mm)**	Category Power Resistor
Control Positive	27.26 ± 0.40 [a]	Very Strong
20%	22.54 ± 0.69 [b]	Very Strong
15%	20.29 ± 0.12 [c]	Strong
10%	15.52 ± 0.25 [d]	Currently
5%	14.37 ± 0.27 [e]	Currently
Control Negative	0.00 ± 0.00 [f]	-

** The values in Table 1 shows the mean values ± standard deviation obtained from four replicates. Values sharing the same letter in the same column indicate no significant difference ($p > 0.05$) based on Duncan's Multiple Range Test (DMRT), following analysis of variance (ANOVA).

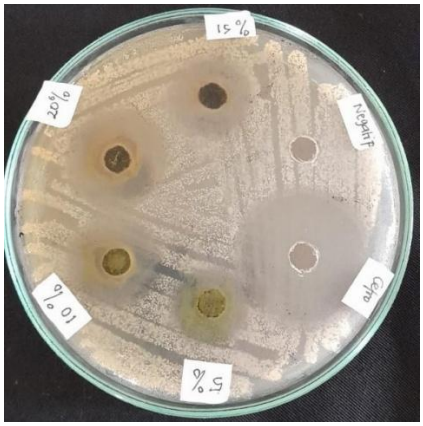

Figure 1. Inhibitor zone of Leaf Extract on Escherichia coli ATCC 25922

The data in Table 1 show that the antibacterial effect of the leaf extract on E. coli ATCC 25922 was highest at the 20 percent concentration, with a mean inhibition zone diameter of 22.54 mm, which is classified as strong. The lowest activity was observed at a concentration of 5%, resulting in a mean inhibition zone diameter of 14.37 mm, classified

as moderate. The negative control using 96 percent ethanol exhibited no inhibition zone, indicating a lack of antibacterial effect. In contrast, the positive reference control (ciprofloxacin) produced an inhibition zone with an average diameter of 27.26 mm, classified as very strong.

Phytochemical screening of the ethanolic crude leaf extract showed positive findings for multiple classes of secondary metabolites, including alkaloids, flavonoids, tannins, phenolic compounds, saponins, and steroids.

Table 2. Test Results Phytochemicals Extract Rough Leaf Excited

Group Compound	Reagent	Change Color	Results
Alkaloid	Mayer	Cloudy and Formed Sediment	+
Flavonoid	Mg + HCl	Formed color yellow	+
Steroid	CH_3COOH glacial + H_2SO_4 concentrated	Formed color green, red , blue	+
Phenol	$FeCl_3$	Formed color chocolate green Black	+
Tannin	$FeCl_3$	Formed color chocolate greenish Black	+
Saponin	Aquadest , shaken	Formed foam	+

Information :
+ = Reaction Positive
- = Reaction Positive

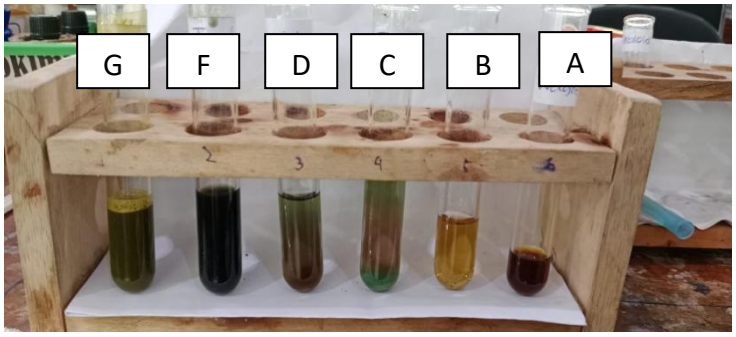

Figure 2. Test Results Phytochemicals Compound Leaf Excited (A) Alkaloids, (B) Flavonoids, (C) Steroids (D) Phenols , (E) (B) Tannin , (F) Saponin.

The ethanolic leaf extract exerted a significant effect ($p < 0.05$) on the growth of *E. coli* ATCC 25922 (Table 1), as evidenced by differences in the inhibition zone diameters observed surrounding the wells (Figure 1). These results are in agreement with earlier reports reporting that Leea indica leaf extract exhibits antibacterial activity against Staphylococcus epidermidis and Salmonella typhi, the causative agents of nosocomial infections and typhoid fever (17). Methanol extracts of L. indica leaves have shown antimicrobial effects against E. coli and S. aureus, with minimum lethal concentration

values (MLC) as low as 16 µg/mL for both bacteria. The active compound identified, cytisoside, was effective against these pathogens, indicating the potential of L. indica as a potential source of antimicrobial compounds (30). *Leea indica* leaf extract demonstrates marked antibacterial activity across various bacterial species, including Staphylococcus epidermidis and Salmonella typhi species, which are known to cause nosocomial (hospital-acquired) infections and typhoid fever, respectively (17) In laboratory tests, the ethanolic extract derived from Leea indica leaves produced measurable inhibitory zones against Gram-positive as well as Gram-negative bacteria including S. typhi strains (3). Increasing the concentration of antimicrobial extracts amplifies their ability to penetrate bacterial cells, disrupt membranes, and damage metabolic systems, leading to more effective bacterial inhibition and cell death. This dose-dependent effect is well-supported across various natural extracts and bacterial targets (26)

The phytochemical test results of Leea indica leaf extract showed positive reactions for several groups of active compounds (Table 2). This finding is consistent with the study of Rahman (2013), who reported that L. indica leaf extract contains alkaloids, flavonoids, tannins, saponins, steroids, and terpenoids. Alkaloids were detected in the alkaloid group assay and are widely recognized for their antibacterial and antifungal activities (29). Their mechanism of action involves inhibition of DNA and RNA synthesis by targeting DNA gyrase and topoisomerase enzyme systems, which are essential for cellular replication and transcription processes (21,22). Flavonoids exert inhibitory actions by damaging the bacterial cell wall structure, inactivating enzymes, and disrupting the cellular membrane. The β-ring structure and hydroxyl (-OH) groups of flavonoids play an essential role in antibacterial function (24).

Steroids, as antibacterial agents, can induce liposome leakage. Due to their lipophilic nature, steroids interact with cell membrane phospholipids, leading to decreased membrane integrity and morphological alterations that result in cell lysis (25). Phenolic compounds are characterized by broad antibacterial effects against Gram-positive as well as Gram-negative bacteria (26). Their Their mode of action includes protein coagulation, which causes membrane lysis; once the membrane is disrupted, phenols penetrate the cells and interfere with cellular metabolic processes (27).

Tannins, which are derivatives of phenols, are widely distributed in wood, stems, leaves, and fruits. Their antimicrobial activity is attributed to interactions with cell membranes and inactivation of genetic material. In addition, tannins form complexes with proteins, causing protein denaturation and thereby disrupting cellular metabolism (27). More broadly, phenolic compounds act as antibacterials by denaturing proteins and inhibiting nucleic acid synthesis (28). Saponins, another active compound, exert detergent-like effects by reducing interfacial tension, thereby increasing membrane membrane permeability and leading to the leakage of intracellular constituents, which ultimately results in membrane disruption and cellular lysis (23, 28).

CLINICAL IMPLICATION

The clinical implication of this study is to provide preliminary information on the secondary metabolites of the traditional plant Leea indica leaves, further in vivo and clinical studies are necessary to confirm their potential therapeutic applicability.

LIMITATIONS

The limitation of this study is use of a single extraction solvent may have restricted the diversity of secondary metabolites obtained, potentially affecting the observed antibacterial activity. In addition, antibacterial testing was limited to one bacterial strain, *Escherichia coli* ATCC 25922, which constrains the generalizability of the findings. As the the study was performed under in vitro experimental conditions, the findings should be interpreted as preliminary. Future research should involve multiple extraction solvents, a broader range of bacterial pathogens, and in vivo studies to better validate the antibacterial capability of Leea indica leaf-derived extract.

CONCLUSIONS

This study demonstrates that the ethanol-based extract obtained from Leea indica leaves exhibits antibacterial activity observed under in vitro conditions against *Escherichia coli* ATCC 25922. The presence of multiple secondary metabolites suggests a potential contribution to the observed inhibitory effect. These results offer initial evidence supporting the antibacterial potential of Leea indica leaves and highlight the need for further studies to clarify the mechanism of action and to validate the activity through broader and more advanced experimental approaches.

CONFLICT OF INTEREST

The authors state that this study was carried out without any commercial or financial affiliations that might be interpreted as a conflict of interest.

AUTHOR CONTRIBUTIONS

II was responsible for study design and implementation, data analysis and interpretation, and manuscript preparation. IBD and NLS provided manuscript review and overall supervision.

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DECLARATION OF ARTIFICIAL INTELLIGENCE USE

No artificial intelligence (AI) tools were used in the preparation of this manuscript.

REFERENCES

1. Yeasmin S, Hasan SMT, Chisti MJ, et al. Factors associated with dehydrating rotavirus diarrhea in children under five in Bangladesh: An urban-rural comparison. PLoS ONE. 2022;17(8 August):1–13.
2. Dewi BS, Soleha T, Septiani L, Apriliana E. Eschercia coli Penyebab Diare: Patogenesis, Diagnosis dan Tatalaksana. Medula. 2024;14(5).
3. Priya V, Balasubramanian N, Shanmugaiah V, Karunakaran C. Phytochemical properties of Acalypha indica (L) and its antimicrobial potential against human pathogens. J Pure Appl Microbiol. 2020;14:319-26. doi:10.22207/jpam.14.1.33.
4. Galgano M, Pellegrini F, Catalano E, Capozzi L, Del Sambro L, Sposato A, Lucente M, Vasinioti V, Catella C, Odigie A, Tempesta M, Pratelli A, Capozza P. Acquired bacterial resistance to antibiotics and resistance genes: from past to future. Antibiotics. 2025;14:222. doi:10.3390/antibiotics14030222.
5. Sharma S, Mohler J, Mahajan S, Schwartz S, Bruggemann L, Aalinkeel R. Microbial biofilm: a review on formation, infection, antibiotic resistance, control measures, and innovative treatment. Microorganisms. 2023;11:1614. doi:10.3390/microorganisms11061614.
6. Noori Naeiji M, Vahdat SM. A Study on the Antioxidant and Antimicrobial Properties of the Aerial Parts Extract of Lagerstroemia indica L. J Med Plants By-Prod. 2024;13(Special):825–834.
7. Karim MR, Gonzalez KEM, Alberta NAA, Besong SA. Phytochemical Analysis and Antioxidant Activities of Prunus africana Bark, Leea indica and Paullinia pinnata Leaf Extracts. Antioxidants. 2025;14:1–17.
8. Darmadi AAK, Sudirga SK, Suriani NL, Wahyuni IGAS. Antifungal Activities of Cinnamon Leaf Extracts Against Sigatoka Fungus (Pseudocercospora fijiensis). IOP Conf Ser Earth Environ Sci. 2019.
9. Putra IKW, Putra G, Wrasiati LP. Pengaruh Perbandingan Bahan dengan Pelarut dan Waktu Maserasi Terhadap Ekstrak Kulit Biji Kakao (Theobroma cacao L.) Sebagai Sumber Antioksidan. J Rekayasa dan Manajemen Agroindustri. 2020;8(2).
10. Darmadi AAK, Suriani NL, Ginantra IK, Sudirga SK. Effectiveness of Cinnamon Leaf Extract to Control Anthractnose Disease on Large Chilies in Bali, Indonesia. Biodiversitas. 2022;23(6).
11. Kumowal S, Fatmwali, Jayanto I. Uji aktivitas antibakteri nanopartikel ekstrak lengkuas putih (Alpinia galanga) terhadap bakteri Klebsiella pneumoniae. Pharmacon. 2019;8(4):781–790.
12. Raal A, Meos A, Hinrikus T, Heinämäki J, Romāne E. Dragendorff's reagent: historical perspectives and current status of a versatile reagent introduced over 150 years ago at the University of Dorpat, Tartu, Estonia. *Die Pharmazie*. 2020;75(7):??? (review on Dragendorff reagent and typical orange/orange-red precipitate)
13. Muthmainnah B. Skrining fitokimia senyawa metabolit sekunder dari ekstrak etanol buah delima (Punica granatum L.). Med Farmasi. 2017;13(2):1–6.

14. Wahid AR, Safwan. Skrining fitokimia senyawa metabolit sekunder terhadap ekstrak tanaman ranting patah tulang (Euphorbia tirucalli L.). Lumbung Farmasi. 2020;1(1):24–27.
15. Wardhani RRAAK, Akhyar O, Prasiska E. Skrining fitokimia, aktivitas antioksidan, dan kadar total fenol-flavonoid daun dan buah Galam Rawa (Melaleuca cajuputi Roxb). Quantum. 2018;9(2):133–143.
16. Gupta S, Gupta R. Phytochemical analysis and antioxidant evaluation of methanolic extracts from Lepidium sativum seeds and Averrhoa carambola fruits: A comparative analysis. Int J Secondary Metabolite. 2025;12(3):669-82.
17. Silaban H, Bakujai E, Pohan D. Effectiveness test of African leaf ethanol extract against Salmonella typhi bacteria. World J Biol Pharm Health Sci. 2023;13(1). doi:10.30574/wjbphs.2023.13.1.0264.
18. Dominic S, Jat RK. Evaluation of antimicrobial activity of ethanolic extract of Leea indica root. Phytomedicine Journal. 2025;14(1):368-372..
19. Harun A, Rahim NEAA, Jalil MAA, Rosdi NAM, Daud S, Harith SS, et al. Comparative study of antioxidant and antimicrobial activity of root, stem and leaves of Leea indica. Malays J Sci. 2016;35(2):259–274.
20. Ermi A, Fikayuniar L, Fauziah S, Melinda L. Skrining fitokimia dan profil KLT dari fraksi n-heksana dan etil asetat pada kulit Pithecellobium jiringa (Jack) Prain. Jurnal Buana Farma. 2022;2(3):1–7.
21. Seo Y, Kim M, Kim T. Enhanced efficacy of ciprofloxacin and tobramycin against Staphylococcus aureus when combined with Corydalis tuber and berberine through efflux pump inhibition. Antibiotics. 2024;13:469. doi:10.3390/antibiotics13050469.
22. Nur R, Lim L, Letchumanan V, Chan KG, Goh BH, Kalingam R. Antibacterial, antibiofilm and anti-quorum sensing activities of Muntingia calabura methanol leaf extract. Lett Appl Microbiol. 2022;75(6):760-768. doi:10.1111/lam.13595
23. Łomanowska M, Olchowik-Grabarek E, Czerkas K, Abdulladjanova N, Sekowski S. The molecular mechanisms of the antibacterial activity of sumac (Rhus typhina L.) tannin against Pseudomonas aeruginosa. Appl Sci. 2024;14:10728. doi:10.3390/app142210728.
24. Chen X, Yi L, Bai Y, Cao M, Wang W, Shang Z, Li J, Xu M, Wu L, Zhu Z, Zhang J. Antibacterial activity and mechanism of Stevia extract against antibiotic-resistant Escherichia coli by interfering with the permeability of the cell wall and the membrane. Front Microbiol. 2024;15:1397906. doi:10.3389/fmicb.2024.1397906.
25. Veiko A, Olchowik-Grabarek E, Sekowski S, Roszkowska A, Lapshina E, Dobrzyńska I, Zamaraeva M, Zavodnik I. Antimicrobial activity of quercetin, naringenin and catechin: flavonoids inhibit Staphylococcus aureus-induced hemolysis and modify membranes of bacteria and erythrocytes. Molecules. 2023;28:1252. doi:10.3390/molecules28031252.
26. Zhou H, Chen L, Ouyang K, Zhang Q, Wang W. Antibacterial activity and mechanism of flavonoids from Chimonanthus salicifolius S.Y. Hu and its

transcriptome analysis against Staphylococcus aureus. Front Microbiol. 2023;13:1103476. doi:10.3389/fmicb.2022.1103476.

27. Zhang G, Yang Y, Memon F, Hao K, Xu B, Wang S, Wang Y, Wu E, Chen X, Xiong W, Si H. A natural antimicrobial agent: analysis of antibacterial effect and mechanism of compound phenolic acid on Escherichia coli based on tandem mass tag proteomics. Front Microbiol. 2021;12:738896. doi:10.3389/fmicb.2021.738896
28. Ribeiro J, Silva V, Igrejas G, Barros L, Heleno S, Reis F, Poeta P. Phenolic compounds from Pyrus communis residues: mechanisms of antibacterial action and therapeutic applications. Antibiotics. 2025;14:280. doi:10.3390/antibiotics14030280.
29. Thawabteh A, Ghanem A, AbuMadi S, Thaher D, Jaghama W, Karaman R, Scrano L, Bufo S. Antibacterial activity and antifungal activity of monomeric alkaloids. Toxins. 2024;16:489. doi:10.3390/toxins16110489.
30. Geremew A, Palmer L, Johnson A, Reeves S, Brooks N, Carson L. Multi-functional copper oxide nanoparticles synthesized using Lagerstroemia indica leaf extracts and their applications. Heliyon. 2024;10:e30178. doi:10.1016/j.heliyon.2024.e30178.