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Antibacterial Activity of Langsat Leaf Extract (*Lansium domesticum Corr.*) against the In Vitro Growth of *Staphylococcus aureus*

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ABSTRACT

The postpartum period is a phase in which a woman's reproductive organs return to their pre-pregnancy state, followed by the adaptation phase in maternal and infant care. Breastfeeding can be hindered when the mother experiences breast wounds or pain. One of the most common postpartum infections is mastitis, affecting approximately 9–20% of mothers. This study aims to determine the active compounds in langsat leaves and their inhibitory effects on *Staphylococcus aureus* bacteria. A true experimental laboratory design with a post-test–only approach was used to assess the significant differences between treatment and control groups, using langsat leaf extract concentrations of 20% and 40%. Phytochemical analysis showed a positive color reaction (+) indicating the presence of flavonoids and saponins. Total flavonoids (anti-inflammatory) measured using spectrophotometry were found to be 0.50% (w/w). Using the gravimetric method, 10 grams of dried extract contained 5.76% moisture. Univariate analysis showed that in the 20% extract group, 2 samples (33.3%) had no inhibition zone (0 mm), while 4 samples (66.7%) produced an inhibition zone of 1–5 mm. Thus, at 20% concentration, langsat leaf extract demonstrated weak antibacterial activity. In the 40% concentration group, 4 samples (66.7%) showed an inhibition zone of 5 mm, and 2 samples (33.3%) showed an inhibition zone of 6–9 mm. These results indicate an increase in antibacterial activity with higher extract concentration. Bivariate analysis using the Kruskal–Wallis test (due to non-normal data distribution) showed a significant difference ($p < 0.05$) between treatment groups on the inhibition of *Staphylococcus* bacteria: the 40% extract produced an average inhibition zone of 5.83 mm, while the 20% extract produced 2.33 mm. The negative control showed no antibacterial activity (0 mm). The increase in extract concentration corresponded with an enhanced inhibitory effect against *Staphylococcus*, although its effectiveness remained below that of the positive-control antibiotic. Further research is recommended, particularly involving selected postpartum mothers experiencing inflammation or mastitis.

Keywords: Inhibitory Activity; Langsat Leaves; Phytochemical Contentc

INTRODUCTION

Infectious diseases remain one of the world's major health problems and contribute significantly to morbidity and mortality rates, particularly in developing countries. One of the greatest challenges in the management of infectious diseases today is the rising incidence of antimicrobial resistance, which is leading to a decline in the effectiveness of various antibiotics that have long been used as the primary treatment (Morrison & Zembower, 2020). The World Health Organisation (WHO) has identified antimicrobial resistance as one of the global health threats requiring serious attention, as it can increase the duration of treatment, treatment costs, the risk of complications, and mortality rates from infections that were previously easily treatable(Organization, 2024). This situation highlights the need to discover and develop new antibacterial agents that are more effective, safer and sustainable to tackle a range of bacterial infections that are becoming increasingly difficult to treat with conventional antibiotics (Tacconelli et al., 2018).

One pathogenic bacterium that plays a significant role in various cases of human infection is *Staphylococcus aureus*. This Gram-positive bacterium is known to cause a wide range of infections, ranging from skin and soft tissue infections to more severe systemic infections. The ability of *S. aureus* to produce various virulence factors, form biofilms, and develop resistance to various types of antibiotics makes it one of the most extensively studied bacteria in the fields of microbiology and pharmacology. Furthermore, *S. aureus* is frequently identified as the causative agent of infections in wounds, abscesses, mastitis, respiratory tract infections, and nosocomial infections in healthcare settings. The rising prevalence of antibiotic-resistant strains, including methicillin-resistant

Staphylococcus aureus (MRSA), further underscores the urgency of developing alternative antibacterial agents derived from natural sources (Tong et al., 2015).

In recent years, there has been a significant increase in the exploration of medicinal plants as sources of antibacterial bioactive compounds. Various studies have shown that plants contain secondary metabolites with biological activity, such as flavonoids, alkaloids, tannins, saponins, phenolics and terpenoids (Cowan, 1999). These compounds are known to inhibit bacterial growth through various mechanisms, including damaging cell membrane integrity, inhibiting protein synthesis, disrupting energy metabolism, reducing cell wall permeability, and inhibiting biofilm formation. The diversity of these mechanisms of action means that natural plant compounds have the potential to be used as alternatives or complements to modern antibacterial therapies, particularly in addressing the growing problem of antibiotic resistance (Silva et al., 2016).

Indonesia is one of the countries with the highest levels of biodiversity in the world and possesses thousands of plant species with the potential to be developed as sources of medicinal raw materials. The use of traditional medicinal plants has been part of Indonesian culture for centuries and is still practised today as a complementary or alternative therapy (Woerdenbag & Kayser, 2014). Various modern studies have confirmed that a number of plants used empirically in traditional medicine contain active compounds capable of producing significant pharmacological effects (Newman & Cragg, 2020). Therefore, scientific exploration of Indonesia's native plants is crucial for generating scientific evidence to support the development of safe, effective phytopharmaceuticals based on local resources.

One tropical plant with great potential for development as a source of natural antibacterial agents is the langsat (*Lansium domesticum* Corr.). This plant, which belongs to the Meliaceae family, is widely found in Southeast Asia, including Indonesia, Malaysia, Thailand and the Philippines. Until now, people have mainly utilised its fruit as food; however, various studies indicate that other parts of the plant, such as the leaves, fruit peel, seeds and stem, also contain a variety of bioactive compounds with pharmacological activity. Phytochemical studies indicate that *Lansium domesticum* contains flavonoids, saponins, tannins, alkaloids, phenolics, triterpenoids, limonoids and various other bioactive compounds with potential antioxidant, anti-inflammatory, antimicrobial, anticancer and immunomodulatory properties (Abdallah et al., 2022);(Mayanti et al., 2022).

The antibacterial activity of various parts of the *Lansium domesticum* plant has been reported in a number of studies. Extracts from the seeds, fruit peel and leaves have been reported to inhibit the growth of several pathogenic bacteria, both Gram-positive and Gram-negative. This activity is thought to be related to the presence of flavonoids and phenolic compounds, which can cause damage to the bacterial cell membrane structure, thereby disrupting the physiological function of the cells. Furthermore, saponins are known to increase the permeability of bacterial cell membranes, leading to the leakage of intracellular components, whilst tannins can precipitate proteins and inhibit the activity of enzymes required for bacterial metabolism. These various mechanisms indicate that *Lansium domesticum* holds promising prospects as a source of natural antibacterial agents (Mayanti et al., 2022).

Nevertheless, most previous studies have focused primarily on extracts from langsat seeds and fruit peel, whilst research specifically evaluating the antibacterial activity of langsat leaf extracts remains relatively limited. Furthermore, the available research findings show considerable variation in extraction methods, solvent types, extract concentrations, antibacterial testing methods, and the types of test bacteria used (Abdallah et al., 2022). These variations make it difficult to directly compare research findings and necessitate further verification. Several studies have reported fairly good antibacterial activity against *Staphylococcus aureus*; however, data regarding the relationship between increasing concentrations of langsat leaf extract and the effectiveness of bacterial growth inhibition remain inconsistent (Mayanti et al., 2022).

Another limitation identified in previous studies is the lack of information regarding the phytochemical characteristics of langsat leaf extracts associated with their antibacterial activity. Some studies merely report the presence of antibacterial activity without identifying the secondary metabolites that may play a role in this activity (Mayanti et al., 2022). However, information on phytochemical composition is crucial for elucidating the biological mechanisms underlying the antibacterial activity of a plant extract. Furthermore, studies evaluating langsat leaf extract against *Staphylococcus aureus* using specific concentration variations remain relatively scarce; therefore, further research is required to strengthen the available scientific evidence (Abdallah et al., 2022).

Based on this literature review, there are research gaps that still need to be addressed. Firstly, research on the antibacterial activity of langsat leaf extract against Staphylococcus aureus remains limited compared to studies on other plant parts. Secondly, the relationship between variations in the concentration of langsat leaf extract and its ability to inhibit the growth of Staphylococcus aureus requires further investigation. Thirdly, information regarding the phytochemical composition of langsat leaf extract that contributes to its antibacterial activity has not yet been widely reported. Therefore, research is needed that can integrate phytochemical analysis with antibacterial activity testing to provide a more comprehensive understanding of the potential of langsat leaf extract as a source of natural antibacterial agents.

This study aims to identify the phytochemical composition of langsat leaf extract (*Lansium domesticum* Corr.) and to evaluate its antibacterial activity against the

growth of Staphylococcus aureus in vitro using the diffusion method. It is hoped that this study will make a scientific contribution by providing experimental evidence of the effectiveness of langsat leaf extract in inhibiting the growth of pathogenic bacteria, whilst strengthening the scientific basis for the utilisation of indigenous Indonesian plants as sources of natural antibacterial agents. Furthermore, the results of this study are expected to serve as a foundation for further research into the isolation of active compounds, the determination of minimum inhibitory concentrations, toxicity testing, and the development of phytopharmaceutical formulations with potential for use in the healthcare sector.

METHODS

Research Design

A true experimental laboratory study design (post-test only) was employed to determine significant differences between the treatment and control groups with concentration variations of 20% and 40% in langsat leaves. Each group was replicated six times. The number of replicates was determined in accordance with the principles of laboratory experimental research, which recommend a minimum of five to six replicates per treatment group to enhance the validity and reliability of the measurement results and to minimise biological and technical variation during the testing of antibacterial activity.

Plant Material and Extraction Procedures

Three kilograms of fresh langsat leaves were dried to yield 655 g of dried crude drug. Extraction was carried out at the Pharmacy Laboratory of the Bogor Agricultural University (IPB) using the maceration method. A total of 655 g of dried plant material powder was macerated using 70% ethanol as the solvent at a material-to-solvent ratio of 1:10 (w/v). The maceration process was carried out for 72 hours at room temperature with periodic stirring to optimise the process.

Extraction of active compounds.

The filtrate from the maceration was then filtered and concentrated using a *rotary evaporator* until a concentrated extract was obtained. From 655 grams of dried crude drug, 100 grams of concentrated extract were obtained. The extract yield was calculated using the formula: Yield (%) = (Weight of extract / Weight of dried crude drug) × 100. Based on these calculations, the extract yield was found to be 15.27%. The concentrated extract was subsequently diluted using dimethyl sulphoxide (DMSO) to obtain test concentrations of 20% and 40%.

Standardisation of the Extract

Extract standardisation was carried out to ensure the quality and consistency of the extract used in the study. Organoleptic observations indicated that the langsat leaf extract was in the form of a concentrated extract, brownish-black in colour, and possessed the characteristic aroma of langsat leaves.
Non-specific parameters examined included the extract's moisture content, determined using the gravimetric method. Measurement results indicated a moisture content of 5.76%. In addition, an analysis of total flavonoid content was carried out using UV–Vis spectrophotometry, which indicated a flavonoid content of 0.50% (w/w).

Phytochemical Analysis

Phytochemical tests were conducted to identify secondary metabolites in the langsat leaf extract. Qualitative tests were performed to detect the presence of flavonoids, tannins, alkaloids, and saponins via colour reactions. The total flavonoid content was measured using UV–Vis spectrophotometry and expressed as a percentage (% w/w). The moisture content of the extract was measured using the gravimetric method.

Test Bacteria and Inoculum Preparation

The test bacterium used was **Staphylococcus aureus**, obtained from the Integrated Microbiology Laboratory at the Banten Ministry of Health Polytechnic. The bacterial suspension was standardised to a McFarland turbidity standard of 0.5 prior to the antibacterial testing.

Antibacterial Activity Test

The antibacterial inhibition test was conducted using the disc diffusion (Kirby–Bauer) method. Sterile filter discs were spotted with langsat leaf extract at concentrations of 20% and 40%. Discs containing the antibiotic chloramphenicol were used as the positive control, whilst discs containing DMSO were used as the negative control. The discs were placed on Mueller–Hinton agar medium inoculated with *S. aureus* and incubated at 37°C for 24 hours. The diameter of the inhibition zone was measured in millimetres using a digital calliper.

Data Processing and Analysis

The design of the univariate data analysis aimed to present a frequency distribution of each variable, whilst the bivariate analysis was used to analyse the relationship between independent and dependent variables, using the ANOVA test if the data were normally distributed; however, if the data were not normally distributed, the Kruskal–Wallis test was used.

Research Ethics

This study received ethical approval from the Health Research Ethics Committee of Poltekkes Kemenkes Semarang (No. 1079/EA/F.XXIII.38/2025; valid from 13 August 2025 to 13 August 2026). Although this research was conducted entirely as an in vitro laboratory experiment and did not involve direct human participants, the collection of human biological specimens, or animal experimentation, ethical approval was obtained in accordance with institutional policy governing biomedical

research. Therefore, informed consent was not required for this study.

RESULTS AND DISCUSSION

Natural Langsat Leaf Material: 1 sack weighing 3 kg yielded 655 g of dried crude drug. Extraction was carried out to obtain 100 g of extract from the crude drug using 70% ethanol as the solvent at a ratio of 1:10, and the extracts were prepared as solutions at concentrations of 20% and 40% using 20% DMSO, with the desired volume of 10 ml or 10 cc. The procedure was carried out at the IPB Laboratory; following completion, bacterial testing was conducted at the Integrated Laboratory of the Banten Ministry of Health Polytechnic of Public Health (Poltekkes Kemenkes Banten). The antibacterial activity of langsat leaf extract against *Staphylococcus aureus* is illustrated in Figure 1."

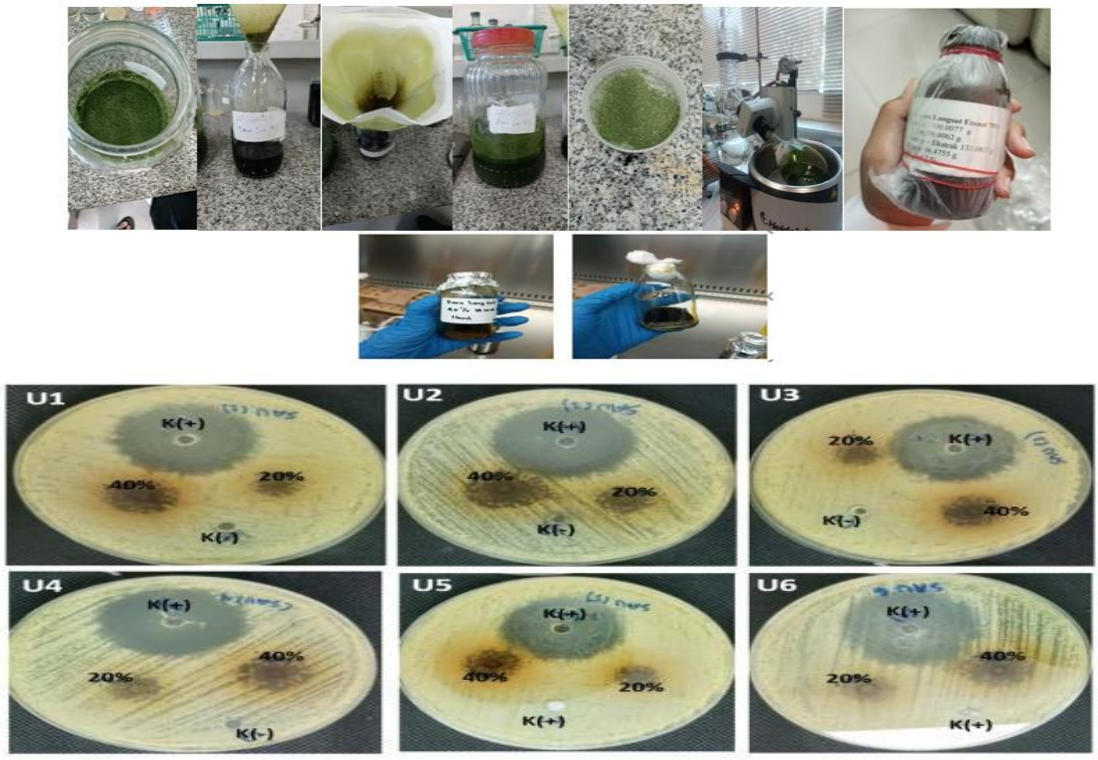

Figure 1. Inhibition zones of Langsat leaf extract against *Staphylococcus aureus* at different concentrations

Table 1.
Distribution of inhibition zone diameters according to treatment group

Group	Inhibition Zone (mm)	Frequency	Percentage (%)
20% extract	0	2	33.3
	1–5	4	66.7
40% extract	5	4	66.7
	6–9	2	33.3
Positive control	15–20	6	100
Negative control	0	6	100

Based on the frequency distribution of the inhibition zone values, it was found that langsat leaf extract (*Lansium domesticum*) exhibited the ability to inhibit the growth of *Staphylococcus aureus*, with varying degrees of inhibition across the treatment groups. In the 20% extract group, the majority of samples (66.7%) exhibited inhibition zones in the range of 1–5 mm, whilst the remaining 33.3% showed no inhibitory activity at all (0 mm). Meanwhile, the 40% extract group showed increased antibacterial activity, with 66.7% of samples falling within the 5–9 mm range and the remainder (33.3%) within the >5 mm range. The positive control group (antibiotic) showed large inhibition zones in the 15–20 mm range (100%), whilst the negative control showed no inhibition zones at all (0 mm).

Table 2 presents the descriptive statistics for the diameter of the inhibition zone across all treatment groups. The 20% langsat leaf extract group had a mean inhibition zone diameter of 2.33 ± 2.07 mm, with a median of 3.0 mm, an interquartile range of 0–3 mm, and a minimum–maximum range of 0–5 mm. A mean rank of 9.50 indicates that this group exhibits relatively low antibacterial activity compared with the other groups. In the 40% extract group, the mean inhibition zone diameter increased to 5.83 ± 1.60 mm, with a median of 5.0 mm,

an interquartile range of 5–6 mm, and a range of 5–9 mm. A mean rank of 16.50 indicates an increase in antibacterial activity compared with the 20% extract group. The positive control group produced the highest mean inhibition zone diameter of 16.67 ± 2.07 mm, with a median of 16.0 mm, an interquartile range of 15–18 mm, and a range of 15–20 mm. This group had the highest mean rank (23.50), indicating the strongest antibacterial efficacy among all groups. Conversely, the negative control showed no antibacterial activity, with a mean of 0.00 ± 0.00 mm, a median of 0 mm, an interquartile range of 0–0 mm, and a mean rank of 3.50, which was the lowest value in this study.

Table 2.
Descriptive statistics of inhibition zone diameter

Group	n	Mean ± SD (mm)	Median (IQR)	Mean Rank
20% extract	6	2.33 ± 2.07	3 (0–3)	9.50
40% extract	6	5.83 ± 1.60	5 (5–6)	16.50
Positive control	6	16.67 ± 2.07	16 (15–18)	23.50
Negative control	6	0.00 ± 0.00	0 (0–0)	3.50

Table 3.
Kruskal–Wallis analysis of inhibition zone diameter

Variable	Value
Kruskal–Wallis H	20.88
Degrees of freedom	3
p-value	<0.001
Effect size (ε²)	0.91

Table 3 shows a statistically significant difference in the diameter of the inhibition zone amongst the four treatment groups (H = 20.88; df = 3; p < 0.001). A p-value of < 0.001 indicates that there is at least one pair of groups with a significant difference in antibacterial activity. Furthermore, the effect size (ε² = 0.89) indicates a very large effect. This suggests that approximately 89 per cent of the variation in the diameter of the inhibition zone can be explained by differences in the type of treatment administered, indicating that the concentration of langsat leaf extract has a very strong influence on the ability to inhibit the growth of *Staphylococcus aureus.*

Table 4.
Dunn–Bonferroni post hoc comparisons

Comparison	Adjusted p-value	Interpretation
20% vs 40%	0.056	Not significant
20% vs Positive control	0.026	Significant
20% vs Negative control	0.161	Not significant
40% vs Positive control	0.024	Significant
40% vs Negative control	0.014	Significant
Positive control vs Negative control	0.015	Significant

Positive control vs Negative control 0.015 SignificantThe results of the analysis show that the positive control had a significantly larger inhibition zone diameter than both the 20% extract group (adjusted p = 0.026) and the 40% extract group (adjusted p = 0.024). Furthermore, the 40% extract group also produced a significantly larger inhibition zone diameter than the negative control (adjusted p = 0.014). Conversely, no significant difference was found between the 20% and 40% extract groups following Bonferroni correction (adjusted p = 0.056), although the mean inhibition zone diameter increased from 2.33 mm to 5.83 mm. Similarly, the 20% extract group did not differ significantly from the negative control (adjusted p = 0.161). The results of this study indicate that langsat leaf extract (*Lansium domesticum* Corr.) exhibits antibacterial activity against *Staphylococcus aureus* in vitro, as evidenced by the formation of inhibition zones in the treatment groups (Pratama & Jasmiadi, 2023). These findings reinforce the scientific evidence that langsat leaves are a source of bioactive compounds with potential for development as natural antibacterial agents. The inhibitory activity demonstrated by langsat leaf extract is thought to be closely related to the secondary metabolites identified in this study, particularly flavonoids and saponins. Various phytochemical studies report that *Lansium domesticum* contains phenolic compounds, flavonoids, terpenoids, limonoids and saponins that possess biological activity, including antimicrobial activity against various pathogenic bacteria. These findings indicate that the leaves of this plant possess pharmacological potential comparable to that of other plant parts, such as the seeds and fruit peel, which have previously been extensively studied (Abdallah et al., 2022).

The increase in inhibitory activity observed as the extract concentration rises indicates a dose-response relationship commonly found in antibacterial research using natural compounds. Biologically, an increase in extract concentration raises the number of active compounds interacting with bacterial cells, thereby increasing the likelihood of structural damage or disruption to the bacteria's physiological functions (Zhang et al.,

2025). This phenomenon indicates that the antibacterial activity of langsat leaf extract does not occur randomly, but is influenced by the quantity of bioactive compounds available in the test medium. Various studies on medicinal plant extracts also show that an increase in extract concentration is generally accompanied by an increase in the area of the inhibition zone, as more active molecules diffuse into the agar medium and interact with microbial cells (H. Zhou et al., 2023).

The ability of langsat leaf extract to inhibit the growth of *Staphylococcus aureus* has significant biological relevance, given that this bacterium is one of the main pathogens responsible for various infections in humans. *Staphylococcus aureus* is known to cause skin infections, abscesses, mastitis, wound infections and even severe systemic infections. Furthermore, this bacterium's ability to form biofilms makes it more difficult to eliminate, both by antibiotics and by the body's immune system. In the context of maternal health, *S. aureus* is one of the most frequently isolated microorganisms in cases of lactational mastitis; consequently, the search for alternative antibacterial agents derived from natural sources is of great importance in supporting safer and more affordable complementary therapies (Mitchell et al., 2022).

The presence of flavonoids in langsat leaf extract is thought to be the main factor contributing to the antibacterial activity observed in this study. Flavonoids are a group of secondary metabolites commonly found in medicinal plants and have been shown to possess antibacterial activity against various Gram-positive and Gram-negative bacteria. The mechanism of action of flavonoids occurs via various pathways, including disrupting the integrity of the bacterial cell membrane, increasing membrane permeability, inhibiting nucleic acid synthesis, disrupting energy metabolism, and suppressing the expression of genes associated with bacterial virulence. Recent molecular research indicates that flavonoids are capable of causing structural changes in the cytoplasmic membrane of *S. aureus*, thereby inhibiting bacterial growth and reproduction. Furthermore, flavonoids can also disrupt the bacterial communication system, or quorum sensing, which plays a role in biofilm formation and increased virulence (H. Zhou et al., 2023;Xu et al., 2024).

In addition to flavonoids, the presence of saponins in langsat leaf extract may also contribute to the observed antibacterial activity. Saponins possess amphiphilic properties, enabling them to interact with the lipids that make up the bacterial cell membrane. This interaction alters membrane permeability, leading to the leakage of intracellular components essential for bacterial survival (J. Zhou et al., 2024). Recent studies on the antimicrobial activity of saponins indicate that this group of compounds is capable of causing cell membrane disorganisation, inhibiting the growth of microorganisms, and increasing bacterial sensitivity to other antimicrobial compounds. Therefore, it is highly likely that the antibacterial activity of langsat leaf extract does not stem from a single type of compound, but is the result of synergistic action between flavonoids, saponins, and other secondary metabolites present in the extract (Li & Monje-Galvan, 2023).

These findings are consistent with various previous reports stating that the species *Lansium domesticum* exhibits antibacterial activity against pathogenic bacteria. A comprehensive study conducted by Abdallah and colleagues demonstrated that various parts of the langsat plant possess a wide range of biological activities, including antibacterial activity against both Gram-positive and Gram-negative bacteria. This activity is attributed to the presence of phenolic and terpenoid compounds capable of inhibiting microbial growth(Abdallah et al., 2022). Similarly, a systematic review by Mayanti and colleagues concluded that both extracts and pure compounds isolated from *Lansium domesticum* hold great potential as sources of natural antimicrobial agents, promising further development in the fields of pharmacy and healthcare (Mayanti et al., 2022).

Nevertheless, the efficacy of the langsat leaf extract in this study was still lower than that of the positive control, which was a standard antibiotic. This finding is a common result observed in early studies of natural products (Berida et al., 2024). Synthetic antibiotics generally consist of pure active compounds at standardised concentrations, whereas plant extracts remain complex mixtures of various metabolites with relatively low concentrations of active compounds. Therefore, although langsat leaf extract demonstrated significant antibacterial activity, its lower efficacy compared to antibiotics does not mean the extract lacks potential; rather, it indicates that processes of isolation, purification and formulation optimisation are still required to enhance its biological activity (Zouine et al., 2024;Angelini, 2024).

The results of this study also indicate that the antibacterial activity of langsat leaf extract remains in the weak to moderate category. This may be influenced by several factors. Firstly, the total flavonoid content measured in this study was relatively low, meaning that the amount of active compounds diffusing into the agar medium was also limited. Secondly, the disc diffusion method has limitations in evaluating plant extracts because some active compounds have large molecular sizes or low solubility, meaning their diffusion into the agar medium is less than optimal. Thirdly, there may be other active compounds that actually possess strong antibacterial activity but have not yet been fully extracted using 70% ethanol as a solvent. These factors may explain why the increase in antibacterial activity has not yet reached a level of effectiveness equivalent to that of standard antibiotics (Mayanti et al., 2022).

The success of langsat leaf extract in inhibiting *Staphylococcus aureus* has important implications for the development of phytopharmaceuticals based on Indonesia's local resources. Indonesia possesses exceptionally high biodiversity, and many local plants have not yet been fully explored as sources of medicine. The

utilisation of local plants such as langsat could be a promising strategy for producing more affordable and sustainable antibacterial alternatives. Furthermore, the development of local natural products also holds high economic value as it can enhance the utilisation of domestic resources whilst reducing dependence on imported raw materials (Abdallah et al., 2022).

From the perspective of global antimicrobial resistance, the findings of this study are also highly relevant. The rising prevalence of antibiotic-resistant bacteria has spurred the search for new antibacterial compounds from natural sources. Flavonoids and phenolic compounds found in plants are known to have different mechanisms of action to conventional antibiotics, thereby potentially reducing the risk of resistance. Some recent studies have even shown that flavonoids can enhance the effectiveness of antibiotics through synergistic mechanisms, thereby opening up opportunities for the development of combination therapies involving antibiotics and natural compounds. This approach is considered promising in addressing the challenge of ever-increasing bacterial resistance in various countries.

Although this study successfully demonstrated the antibacterial activity of langsat leaf extract against *Staphylococcus aureus*, several limitations must be taken into account when interpreting the results. This study utilised only two concentrations of the extract and therefore cannot fully characterise the dose-response relationship. Furthermore, the study did not determine the Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) values, which are crucial for a more accurate evaluation of antibacterial potential. The study was also limited to in vitro testing; consequently, the extract's effectiveness in more complex biological systems cannot yet be confirmed. Another limitation is the lack of specific identification of the active compounds using chromatography or spectrometry techniques; thus, the compounds primarily responsible for the antibacterial activity remain unknown (H. Zhou et al., 2023).

Given these limitations, future research should focus on the isolation and characterisation of the active compounds contained in langsat leaves using modern analytical methods such as HPLC, LC-MS/MS or GC-MS. Subsequent studies should also evaluate the MIC and MBC values to obtain a more comprehensive picture of the extract's antibacterial potential. Furthermore, testing against antibiotic-resistant clinical strains, including MRSA, is essential to assess the clinical relevance of langsat leaf extract in addressing the problem of antimicrobial resistance. Synergy testing between langsat leaf extract and conventional antibiotics should also be considered, as such combinations have the potential to enhance therapeutic efficacy and reduce the required antibiotic dosage.

Further research should include in vivo testing using animal models as well as limited clinical trials, particularly in cases of mastitis, which is closely associated with *Staphylococcus aureus* infection. In vivo testing will provide information on the bioavailability, safety, toxicity and therapeutic efficacy of the extract under real biological conditions. Furthermore, the development of topical formulations such as gels, creams or ointments based on langsat leaf extract is also a strategic step towards improving the stability, penetration and efficacy of the active compounds at the site of infection. Thus, the results of this study can serve as a strong scientific foundation for the development of safe, effective and sustainable phytopharmaceutical products based on langsat leaves to support the management of bacterial infections in the future (Abdallah et al., 2022).

CONCLUSIONS

This study demonstrates that langsat leaf extract (*Lansium domesticum Corr.*) exhibits antibacterial activity against *Staphylococcus aureus* in vitro, as indicated by its ability to inhibit bacterial growth across all treatment groups. Increasing the extract concentration tends to enhance the antibacterial effect, although its efficacy remains lower than that of standard antibiotics. This antibacterial activity is thought to be related to the presence of secondary metabolites such as flavonoids and saponins, which play a role in disrupting the integrity of bacterial cell membranes and interfering with the physiological processes of the microorganisms. Although the results of this study indicate promising biological potential, these findings are still limited to in vitro laboratory testing and therefore cannot yet be taken as evidence of clinical efficacy in humans. Therefore, the results of this study should be understood as preliminary evidence that still requires further validation through follow-up studies, particularly in vivo trials, toxicity tests, and clinical trials to ensure their safety, efficacy, and relevance in healthcare practice. This study confirms that langsat leaves have the potential to serve as a source of natural antibacterial agents; however, further development is required before they can be applied clinically. This includes the isolation of active compounds, the standardisation of extracts, and the development of appropriate pharmaceutical formulations to support their use in healthcare.

SUGGESTION

Future research should prioritise the standardisation of Lansium domesticum leaf extract through the optimisation of extraction methods, the identification of active antibacterial constituents using chromatography and spectrometry techniques (e.g. HPLC, LC-MS/MS or GC-MS), and the determination of MIC and MBC values. Further investigations should also evaluate cytotoxicity, dermal safety, pharmacokinetic properties, and formulation stability to establish a comprehensive safety profile. Before clinical application is considered, the extract must be validated using appropriate in vivo models to confirm its efficacy and safety. Clinical studies involving postpartum women with mastitis should only be conducted

once robust preclinical evidence has demonstrated favourable toxicity, dosage, and therapeutic profiles.

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