



Formulation and Antibacterial Activity of Anti-Acne Gel Containing Ethanol Extract of Avocado Leaves (*Persea americana* Mill.) Against *Staphylococcus epidermidis*

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Abstract: Acne is a chronic inflammatory skin disorder associated with bacterial colonization, including *Staphylococcus epidermidis*, which contributes to acne lesion development. The increasing concern regarding antibiotic resistance has encouraged the exploration of natural antibacterial agents from medicinal plants. This study aimed to formulate an anti-acne gel containing ethanol extract of avocado leaves (*Persea americana* Mill.) and evaluate its antibacterial activity against *Staphylococcus epidermidis*. Ethanol extract was obtained using the maceration method and subjected to phytochemical screening. The antibacterial activity of the extract was evaluated by determining the Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) using the microdilution method. The extract was subsequently formulated into gel preparations and evaluated for physical characteristics, including organoleptic properties, homogeneity, pH, viscosity, spreadability, adhesion, and antibacterial activity using the agar diffusion method. The results showed that avocado leaf ethanol extract exhibited antibacterial activity with an MIC value of 64,000 µg/mL, while the MBC was not determined within the tested concentrations. The formulated gels met the physical quality requirements, with inhibition zones of 15.0 ± 1.7 mm and 11.0 ± 3.6 mm against *Staphylococcus epidermidis* for Formula I and Formula II, respectively. In conclusion, ethanol extract of avocado leaves can be incorporated into an anti-acne gel preparation with acceptable physicochemical characteristics and antibacterial potential against *Staphylococcus epidermidis*. This study provides preliminary evidence supporting the development of plant-based topical formulations as potential alternatives for acne management.

Keywords: *Anti-acne gel; Persea americana Mill.; ethanol extract; antibacterial activity; Staphylococcus epidermidis*

INTRODUCTION

Acne vulgaris is one of the most common chronic inflammatory skin disorders affecting adolescents and young adults. It is characterized by the formation of comedones, papules, pustules, and nodules resulting from complex interactions involving increased sebum production, follicular hyperkeratinization, microbial colonization, and inflammatory responses. Globally, acne remains one of the most prevalent dermatological conditions and significantly affects patients' quality of life, self-esteem, and psychological well-being. In addition to *Cutibacterium acnes*, other skin microorganisms such as *Staphylococcus epidermidis* have been reported to contribute to acne development through bacterial colonization and interactions with the skin microbiome (Niedzwiedzka et al., 2024).

In Indonesia, acne represents a significant dermatological concern due to the tropical climate conditions that may support microbial growth on the skin. A meta-analysis conducted by Hermawan et al. (2021) reported that *Cutibacterium acnes*, *Staphylococcus epidermidis*, and *Staphylococcus aureus* are among the microorganisms frequently associated with acne vulgaris lesions in Indonesia. Furthermore, the extensive use of topical and systemic antibiotics in acne therapy has become a major challenge due to the increasing prevalence of antimicrobial resistance. Resistance to commonly used antibiotics, including macrolides and clindamycin, has been reported among acne-associated bacteria, highlighting the urgent need for alternative therapeutic agents with improved safety and sustainability profiles (Manica & Hossain, 2026).

The utilization of natural compounds as antibacterial agents has gained considerable attention in pharmaceutical dermatology. Medicinal plants contain various bioactive secondary metabolites, including flavonoids, alkaloids, tannins, saponins, and other phenolic compounds, which exhibit antimicrobial properties. These compounds can inhibit bacterial growth through several mechanisms, such as disruption of bacterial cell membrane integrity, inhibition of cell wall synthesis, interference with enzymatic activity, and disturbance of microbial metabolic processes (Pérez-Flores et al., 2025). The development of natural extracts into topical pharmaceutical preparations represents a promising approach because it enables direct application to the target site and enhances patient convenience.

Avocado leaves (*Persea americana* Mill.) are considered a potential natural source of antibacterial compounds due to their rich phytochemical composition. Previous studies have demonstrated that avocado leaves contain secondary metabolites, including flavonoids, alkaloids, saponins, and tannins, which possess various biological activities. Flavonoids may exert antibacterial effects by altering bacterial membrane permeability and disrupting cellular proteins, alkaloids can inhibit peptidoglycan synthesis, saponins increase membrane permeability leading to intracellular component leakage, while tannins interfere with bacterial enzymes and protein functions. Previous research by Juma (2025) demonstrated that ethanol extract of avocado leaves exhibited antibacterial activity against acne-associated bacteria. However, the study mainly focused on crude extract evaluation and did not explore the development of a topical gel formulation.

Based on previous studies, a research gap remains regarding the transformation of avocado leaf extract into a practical pharmaceutical dosage form. Most previous investigations have focused primarily on evaluating the antibacterial activity of avocado leaf extracts, whereas studies concerning the formulation of anti-acne gel containing ethanol extract of avocado leaves and its physicochemical characteristics as well as antibacterial activity against *Staphylococcus epidermidis* remain limited. Therefore, further investigation is

required to develop a topical gel preparation and evaluate its potential as a plant-based antibacterial agent for acne management.

This study aimed to formulate an anti-acne gel containing ethanol extract of avocado leaves (*Persea americana* Mill.) and evaluate its antibacterial activity against *Staphylococcus epidermidis*. Theoretically, this research contributes to the advancement of pharmaceutical sciences, particularly in the field of natural product development and the relationship between plant secondary metabolites and antibacterial activity. Practically, this study provides scientific evidence supporting the development of plant-based topical preparations as potential alternatives for acne treatment and may contribute to reducing dependence on conventional antibiotic therapies.

Research Hypothesis

Alternative Hypothesis (H_1)

The anti-acne gel containing ethanol extract of avocado leaves (*Persea americana* Mill.) exhibits antibacterial activity against *Staphylococcus epidermidis*.

Null Hypothesis (H_0)

The anti-acne gel containing ethanol extract of avocado leaves (*Persea americana* Mill.) does not exhibit antibacterial activity against *Staphylococcus epidermidis*.

Additional Hypothesis

Different concentrations of ethanol extract of avocado leaves in the gel formulation affect the antibacterial activity against *Staphylococcus epidermidis*.

Research Framework

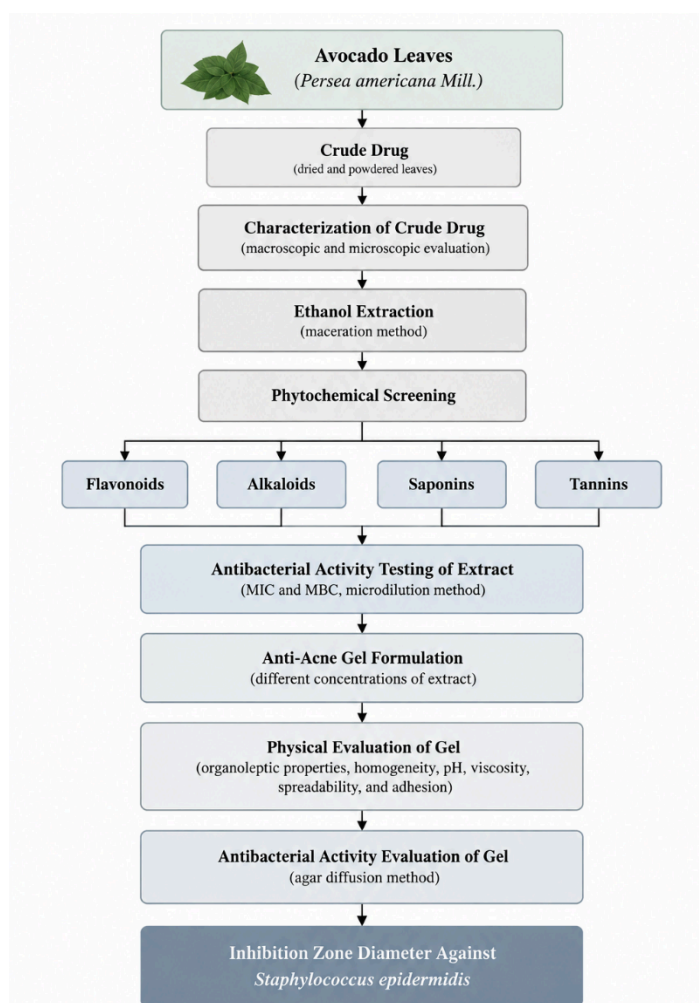


Figure 1. Research Framework of the Formulation and Antibacterial Activity of Anti-Acne Gel Containing Ethanol Extract of Avocado Leaves (*Persea americana* Mill.) Against *Staphylococcus epidermidis*.

METHODS

Research Design and Approach

This study employed a quantitative experimental laboratory approach using a true experimental design to evaluate the antibacterial activity of anti-acne gel containing ethanol extract of avocado leaves (*Persea americana* Mill.) against *Staphylococcus epidermidis*. The quantitative approach was selected because the research generated measurable numerical data, including minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC), physical evaluation parameters of gel preparations, and inhibition zone diameter. Experimental pharmaceutical research is commonly conducted through controlled laboratory procedures to evaluate the relationship between active compounds, formulation characteristics, and biological activity (Da Silva et al., 2023).

The independent variable in this study was the concentration of ethanol extract of avocado leaves incorporated into the gel formulation, while the dependent variables were antibacterial activity and physical characteristics of the gel preparation. The experimental design consisted of several stages, including plant material preparation, crude drug characterization, ethanol extraction, phytochemical screening, antibacterial activity evaluation of the extract, gel formulation, physical evaluation, and antibacterial evaluation of the final gel preparation.

Research Materials and Sample Selection

The research samples consisted of avocado leaves (*Persea americana* Mill.) as plant material and *Staphylococcus epidermidis* as the test microorganism. The plant samples were selected using a non-probability purposive sampling technique because the selection was based on specific criteria, including healthy leaves, free from disease, and suitable morphological characteristics. Purposive sampling is commonly applied in pharmacognostic studies because the quality and identity of plant materials significantly influence the reproducibility of phytochemical and biological activity results (Dedefo et al., 2026).

The bacterial sample used in this study was *Staphylococcus epidermidis*, selected because this microorganism is associated with acne development and represents a relevant bacterial target for evaluating anti-acne antibacterial preparations (Severn & Horswill, 2023). No human participants, respondents, or informants were involved in this study because the research was conducted entirely through laboratory-based biological testing.

Research Instruments and Data Collection Techniques

Data collection was conducted through laboratory observation, physicochemical measurements, and microbiological testing. The instruments used included laboratory equipment for extraction, phytochemical analysis, gel evaluation, and antibacterial testing. The collected data consisted of extraction yield, phytochemical screening results, MIC and MBC values, organoleptic characteristics, homogeneity, pH, viscosity, spreadability, adhesion, and inhibition zone diameter.

The phytochemical screening procedure was performed to identify the presence of secondary metabolites, including flavonoids, alkaloids, saponins, and tannins. Antibacterial activity of the extract was determined using the microdilution method to obtain minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) values. The MIC value was determined by observing the lowest concentration that inhibited visible bacterial growth, while the MBC value was determined by assessing the ability of the extract

to eliminate bacterial viability (Yuandani et al., 2024). Microbiological evaluation using standardized antibacterial assays is widely applied in pharmaceutical research to determine the effectiveness of natural product-based antimicrobial preparations (Cushnie et al., 2020).

Because this study did not involve human subjects, questionnaire instruments, interviews, respondent validation, and reliability testing were not applicable. The validity of the research results was maintained through standardized laboratory procedures, controlled experimental conditions, repeated measurements, and the use of established microbiological and pharmaceutical evaluation methods.

Research Procedure

The research procedure began with the preparation and identification of avocado leaves (*Persea americana* Mill.). The collected leaves were processed into crude drug material through sorting, washing, drying, and pulverization. The crude drug was then characterized through macroscopic and microscopic evaluation as well as physicochemical parameters to ensure the quality of the plant material.

The extraction process was performed using the maceration method with ethanol as the extraction solvent. Maceration was selected because it is an effective extraction method for obtaining bioactive compounds while minimizing thermal degradation of heat-sensitive phytochemicals (Sun et al., 2025). The obtained ethanol extract was subsequently subjected to phytochemical screening to identify secondary metabolites responsible for antibacterial activity.

The antibacterial activity of the ethanol extract was evaluated against *Staphylococcus epidermidis* through MIC and MBC determination using the microdilution method. The extract was then incorporated into an anti-acne gel formulation with different extract concentrations. The prepared gel formulations were evaluated for physical characteristics, including organoleptic properties, homogeneity, pH, viscosity, spreadability, and adhesion.

The final stage involved antibacterial evaluation of the gel preparation using the agar diffusion method. The antibacterial effectiveness was determined based on the diameter of the inhibition zone formed around the tested samples. The results were interpreted to determine the antibacterial potential of avocado leaf ethanol extract gel as a topical anti-acne preparation.

Data Analysis

The obtained quantitative data were analyzed descriptively and statistically according to the characteristics of each parameter. Physical evaluation results, including pH, viscosity, spreadability, adhesion, and inhibition zone diameter, were presented as mean values with standard deviations. The antibacterial activity data were analyzed by comparing inhibition zones between different gel formulations. Statistical analysis was performed using statistical software such as IBM SPSS Statistics version 26. Data normality and homogeneity tests were conducted before further statistical analysis. Differences between formulations were analyzed using appropriate statistical tests with a significance level of $p < 0.05$. Quantitative analysis of antibacterial and physicochemical parameters is commonly applied in pharmaceutical formulation studies to determine the influence of formulation variables on product performance (Ghosh & Lonhare, 2024).

RESULTS

Plant Identification, Sample Processing, and Extraction

The plant identification conducted at Herbarium Medanense (MEDA), Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, confirmed that the investigated sample was avocado leaves (*Persea americana* Mill.) with identification number 125/MEDA/2026. The samples were collected purposively from Sidorejo Village, Gunung

Meriah District, Aceh Singkil Regency, Aceh Province. The fresh avocado leaves obtained weighed 9.7 kg, which were processed into 3.4 kg of dried crude drug and 3 kg of powdered simplicia, resulting in a simplicia yield of 30%. Extraction using the maceration method with 96% ethanol produced 256 g of ethanol extract from 1000 g of simplicia, with an extraction yield of 26.5%.

Table 1. Processing and Extraction Yield of Avocado Leaves (*Persea americana* Mill.)

Parameter	Result
Fresh leaf weight	9.7 kg
Dried simplicia weight	3.4 kg
Powdered simplicia weight	3 kg
Simplicia yield	30%
Ethanol extract weight	256 g
Extract yield	26.5%

Characterization of Avocado Leaf Simplicia

Microscopic examination revealed characteristic anatomical structures of avocado leaves, including cuticle, upper epidermis, palisade tissue, oil cells, lower epidermis, stomata, vascular bundles, sclerenchyma fibers, and covering trichomes. The physicochemical characterization results showed that avocado leaf simplicia met the requirements of the Indonesian Herbal Pharmacopoeia (FHI Edition II), except for the ash insoluble in acid parameter, which slightly exceeded the specified limit.

Table 2. Physicochemical Characterization of Avocado Leaf Simplicia

Parameter	Result (%)	FHI Requirement (%)
Moisture content	4.00	≤10
Water-soluble extractive content	20.88	≥14.6
Ethanol-soluble extractive content	14.98	≥13.5
Total ash content	3.45	≤4.2
Acid-insoluble ash content	1.13	≤1.1

Phytochemical Screening

Phytochemical screening of ethanol extract of avocado leaves showed positive results for alkaloids, flavonoids, saponins, and tannins.

Table 3. Phytochemical Screening of Ethanol Extract of Avocado Leaves

Secondary Metabolite	Result
Alkaloids	Positive (+)
Flavonoids	Positive (+)
Saponins	Positive (+)
Tannins	Positive (+)

Antibacterial Activity of Ethanol Extract

The antibacterial activity of avocado leaf ethanol extract was evaluated against *Cutibacterium acnes* and *Staphylococcus epidermidis* using the microdilution method. The extract showed inhibitory activity at concentrations of 64,000 µg/mL and 128,000 µg/mL. The Minimum Inhibitory Concentration (MIC) of the extract against both bacteria was 64,000 µg/mL, while the Minimum Bactericidal Concentration (MBC) was not determined because bacterial growth remained after subculture.

Table 4. Antibacterial Activity of Avocado Leaf Ethanol Extract

Parameter	Result
Test bacteria	<i>Cutibacterium acnes</i> and <i>Staphylococcus epidermidis</i>
Method	Microdilution
MIC	64,000 µg/mL
MBC	Not determined

Physical Evaluation of Anti-Acne Gel Formulation

The ethanol extract was formulated into three gel preparations: F0 (without extract), F1 (6.4% extract), and F2 (12.8% extract). All formulations showed acceptable organoleptic properties and homogeneous characteristics. The pH values of F0, F1, and F2 were 4.95, 4.98, and 5.10, respectively. The viscosity values were 36,120 cP, 35,363 cP, and 36,683 cP. The spreadability and adhesion tests showed that all formulations met the required characteristics of topical gel preparations.

Table 5. Physical Evaluation of Anti-Acne Gel

Parameter	F0	F1	F2
pH	4.95	4.98	5.10
Viscosity (cP)	36,120	35,363	36,683
Homogeneity	Homogeneous	Homogeneous	Homogeneous
Adhesion time	3 min 36 s	1 min 55 s	2 min 7 s

Antibacterial Activity of Gel Against *Cutibacterium acnes*

The formulated gels exhibited antibacterial activity against *Cutibacterium acnes*. The inhibition zones of the positive control, F0, F1, and F2 were 13.4 ± 3.7 mm, 10.1 ± 1.6 mm, 10.1 ± 1.6 mm, and 8.9 ± 0.9 mm, respectively.

Table 6. Inhibition Zone Diameter of Gel Against *Cutibacterium acnes*

Formulation	Inhibition Zone (mm) $\pm$ SD	Category
Positive control	13.4 ± 3.7	Strong
F0	10.1 ± 1.6	Strong
F1 (6.4%)	10.1 ± 1.6	Strong
F2 (12.8%)	8.9 ± 0.9	Moderate

Statistical analysis using One-Way ANOVA showed no significant difference among formulations ($p = 0.166$).

Antibacterial Activity of Gel Against *Staphylococcus epidermidis*

All gel formulations demonstrated antibacterial activity against *Staphylococcus epidermidis*. The inhibition zones of the positive control, F0, F1, and F2 were 14.4 ± 2.4 mm, 11.3 ± 3.4 mm, 15.0 ± 1.7 mm, and 11.0 ± 3.6 mm, respectively.

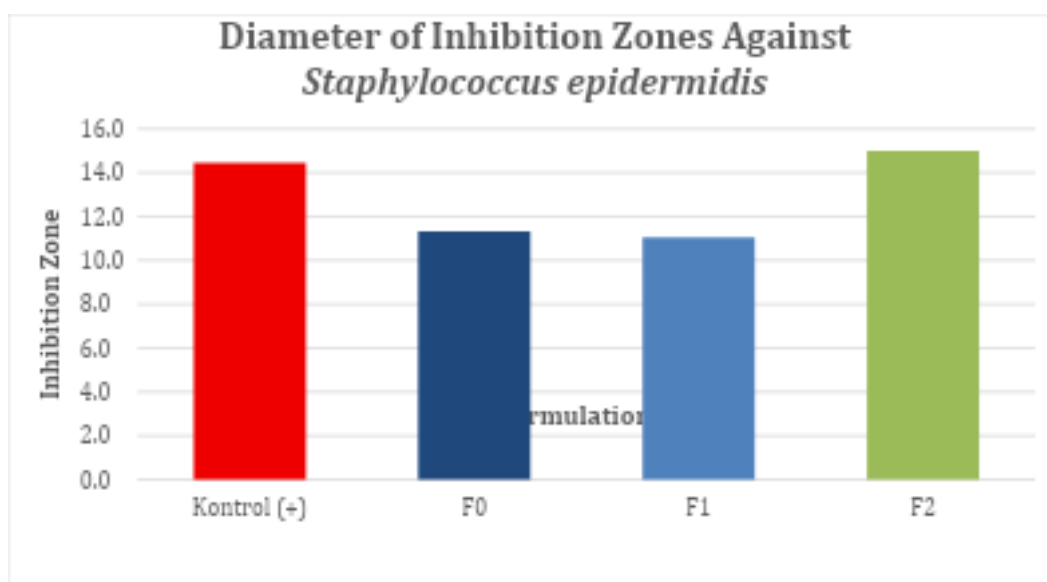


Figure 1. Diameter of Inhibition Zones of Anti-Acne Gel Formulations Against *Staphylococcus epidermidis*

Table 7. Inhibition Zone Diameter of Gel Against *Staphylococcus epidermidis*

Formula	Inhibition Zone (mm) $\pm$ SD	Category
Positive control	14.4 $\pm$ 2.4	Strong
F0	11.3 $\pm$ 3.4	Strong
F1 (6.4%)	15.0 $\pm$ 1.7	Strong
F2 (12.8%)	11.0 $\pm$ 3.6	Strong

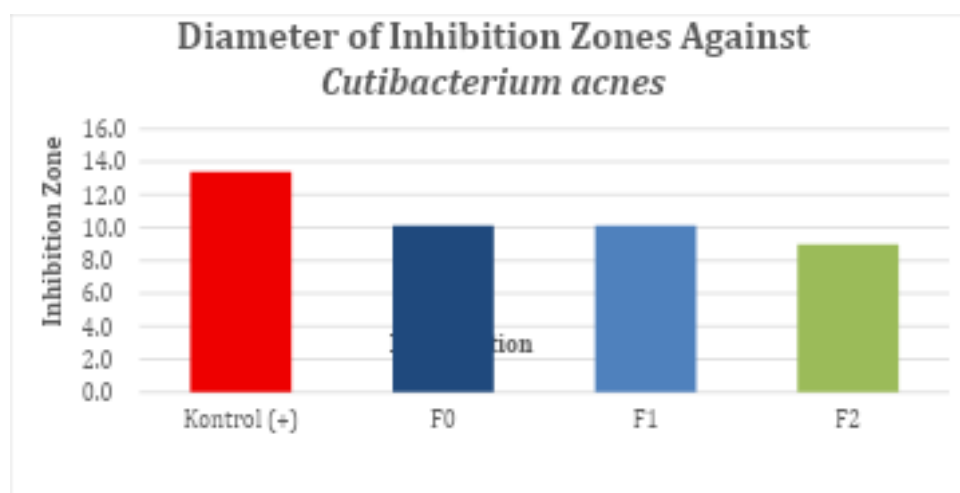


Figure 2. Diameter of Inhibition Zones of Anti-Acne Gel Formulations Against *Cutibacterium acnes*

The Shapiro–Wilk test showed normally distributed data, and Levene’s test indicated homogeneous variance. One-Way ANOVA analysis showed no significant difference among formulations ($p = 0.280$).

DISCUSSION

The identification and characterization results confirmed that the investigated plant material was avocado leaves (*Persea americana* Mill.), ensuring the authenticity of the

sample used in this study. Proper botanical identification is an essential step in pharmacognostic research because variations in plant species, geographical origin, and environmental conditions may affect the consistency of phytochemical composition and biological activity (Osungunna, 2020). The extraction process using 96% ethanol through maceration produced an extract yield of 26.5%. Ethanol was selected as the extraction solvent because it is capable of extracting various polar and semi-polar secondary metabolites, including flavonoids, alkaloids, tannins, and saponins. The presence of these compounds in avocado leaves has been widely reported to contribute to biological activities, particularly antibacterial effects (Anggreni & Udayani, 2025). Ethanol extraction is frequently applied in medicinal plant research due to its effectiveness in recovering a broad range of bioactive compounds while maintaining chemical stability (Cetinkaya et al., 2025). The yield obtained in this study indicates that the maceration method was effective in extracting bioactive compounds from avocado leaves. Differences in extraction yield may occur due to variations in plant origin, environmental conditions, solvent concentration, extraction duration, and plant material preparation.

The physicochemical characterization of avocado leaf *simplicia* showed that most parameters fulfilled the requirements of the Indonesian Herbal Pharmacopoeia (FHI Edition II). The moisture content obtained was 4%, indicating that the *simplicia* had good stability and a lower risk of microbial contamination during storage. Moisture content is an important quality parameter for herbal materials because excessive water content may accelerate enzymatic degradation and microbial growth, affecting the stability of active compounds (Pawar et al., 2025). The extractive values of water-soluble and ethanol-soluble compounds were 20.88% and 14.98%, respectively, indicating the presence of both polar and semi-polar compounds. However, the acid-insoluble ash value was slightly above the specified limit (1.13%), suggesting the possibility of minor inorganic contamination during processing. Therefore, although the *simplicia* generally showed good quality characteristics, improved processing control is required to minimize external contamination and ensure consistent quality of herbal materials.

Phytochemical screening demonstrated that ethanol extract of avocado leaves contained alkaloids, flavonoids, saponins, and tannins. These secondary metabolites are considered responsible for the antibacterial potential of plant extracts. Plant-derived secondary metabolites have been widely investigated due to their ability to interfere with bacterial growth through multiple mechanisms (Mulat et al., 2025). Flavonoids have been reported to exert antibacterial effects through disruption of bacterial cell membranes, inhibition of nucleic acid synthesis, interference with energy metabolism, and inhibition of biofilm formation (Weng et al., 2024). Alkaloids may interfere with bacterial cell wall formation, while tannins can bind to bacterial proteins and enzymes, resulting in inhibition of microbial growth. Saponins may contribute through their ability to increase membrane permeability, leading to leakage of intracellular components. The presence of these compounds supports the potential mechanism underlying the antibacterial activity observed in this study.

The antibacterial evaluation of avocado leaf ethanol extract showed a Minimum Inhibitory Concentration (MIC) value of 64,000 µg/mL against *Cutibacterium acnes* and *Staphylococcus epidermidis*, while the Minimum Bactericidal Concentration (MBC) was not determined because bacterial growth remained after subculture. These findings indicate that the extract exhibited inhibitory activity but was not able to completely eliminate bacterial growth at the tested concentrations. Similar findings have been reported by Le Thi et al. (2025), who demonstrated that ethanol extract of avocado leaves possessed antibacterial activity against acne-associated bacteria. Differences in antibacterial effectiveness between studies may be influenced by extraction procedures, extract concentration, bacterial strain characteristics, and differences in antibacterial testing methods. Variations in antibacterial

response between plant extracts are commonly associated with differences in phytochemical profiles, bacterial susceptibility, and experimental conditions (Bubonja-Šonje et al., 2020).

The formulated anti-acne gel preparations showed acceptable physical characteristics, including homogeneous appearance, suitable pH values, viscosity, spreadability, and adhesion properties. The pH values of all formulations ranged from 4.95 to 5.10, which is within the physiological range of facial skin. Maintaining an appropriate pH is important because topical preparations with pH values close to skin conditions may reduce irritation risk and support skin barrier stability. The viscosity results indicated that all formulations possessed suitable consistency for topical application. The physical stability observed in this study demonstrates that ethanol extract of avocado leaves can be incorporated into a gel dosage form without significantly affecting the basic characteristics of the preparation.

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The antibacterial activity of the formulated gels showed that all formulations produced inhibition zones against *Cutibacterium acnes* and *Staphylococcus epidermidis*. Against *Staphylococcus epidermidis*, Formula F1 containing 6.4% extract produced the highest inhibition zone (15.0 ± 1.7 mm), whereas increasing the extract concentration to 12.8% in F2 resulted in a lower inhibition zone (11.0 ± 3.6 mm). This result indicates that increasing extract concentration did not directly increase antibacterial activity. The phenomenon may be related to the diffusion ability of active compounds through the agar medium, interaction between extract components and gel matrix, or differences in active compound release from the formulation. Previous studies have also shown that the antibacterial activity of plant-based topical preparations is not always linearly correlated with extract concentration because formulation characteristics may influence active compound availability (Berga et al., 2023). The release and diffusion behavior of active compounds from topical preparations are influenced by polymer structure, viscosity, and interactions between active ingredients and excipients (Modh et al., 2026).

Statistical analysis showed that the antibacterial activity differences among formulations were not statistically significant for either *Cutibacterium acnes* ($p = 0.166$) or *Staphylococcus epidermidis* ($p = 0.280$). Although F1 demonstrated the highest antibacterial activity against *Staphylococcus epidermidis*, the difference between formulations was insufficient to produce significant statistical variation. The antibacterial activity observed in the control gel (F0) also suggests that other components within the gel base may contribute to inhibition, particularly preservatives and supporting ingredients with potential antimicrobial effects. Previous studies have reported that excipients used in topical formulations may influence antimicrobial performance, especially when antimicrobial preservatives or penetration-enhancing agents are incorporated into the formulation (Raab et al., 2025).

This study demonstrates that ethanol extract of avocado leaves (*Persea americana* Mill.) has potential as a natural antibacterial ingredient in anti-acne gel formulations, particularly against *Staphylococcus epidermidis*. However, several limitations should be considered, including the absence of in vivo evaluation, limited bacterial strains, and the lack of further analysis regarding active compound concentration and release profile from the gel

matrix. Future studies should investigate optimization of extract concentration, evaluation of stability during storage, identification of specific antibacterial compounds, and clinical assessment to confirm the effectiveness and safety of avocado leaf-based anti-acne preparations. Overall, this research provides preliminary scientific evidence supporting the development of plant-based topical formulations as potential alternatives for acne management.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

This study demonstrated that ethanol extract of avocado leaves (*Persea americana* Mill.) can be successfully incorporated into an anti-acne gel formulation with acceptable physicochemical characteristics. The extract exhibited antibacterial activity against *Staphylococcus epidermidis* with a Minimum Inhibitory Concentration (MIC) value of 64,000 µg/mL, although the Minimum Bactericidal Concentration (MBC) was not determined within the tested concentrations. The formulated gels showed suitable characteristics, including acceptable pH, viscosity, homogeneity, spreadability, and adhesion properties, indicating their potential as topical pharmaceutical preparations.

The findings provide preliminary scientific evidence supporting the utilization of avocado leaves as a natural antibacterial ingredient for the development of herbal-based anti-acne formulations. However, the antibacterial activity was not significantly influenced by different extract concentrations, indicating that further formulation optimization is required to improve active compound availability and antibacterial performance. This study contributes to the advancement of natural product-based pharmaceutical development, particularly in the exploration of plant-derived ingredients for topical dermatological applications.

Limitations

This study has several limitations. First, the antibacterial evaluation was limited to laboratory-based testing against selected acne-associated bacteria, so the findings cannot yet be generalized to broader clinical applications. Second, the study evaluated antibacterial activity based on inhibition zones and MIC/MBC parameters without further analysis of active compound concentration, release profile, and mechanism of action within the gel formulation. Third, the research did not include long-term stability testing or in vivo evaluation, which are important to confirm the safety, effectiveness, and practical application of avocado leaf-based anti-acne gel preparations. Therefore, the results should be interpreted within the scope of the experimental conditions applied in this study.

Recommendations

Future research should optimize the concentration of ethanol extract of avocado leaves to improve antibacterial effectiveness and obtain more accurate MIC and MBC values. Further studies are also recommended to evaluate different topical dosage forms, such as creams, ointments, or emulgels, to compare their physicochemical characteristics and antibacterial performance. In addition, stability studies, evaluation against broader bacterial strains, identification of specific active compounds, and in vivo investigations are needed to support the development of avocado leaf extract as a safe and effective herbal anti-acne preparation.

Author Contributions

All authors contributed significantly to this study. The contributions included research conceptualization, methodology development, experimental design, data collection, laboratory analysis, interpretation of results, manuscript preparation, critical revision, and final approval

of the submitted manuscript. All authors have read and approved the final version of the article for publication.

Acknowledgment

The authors would like to express their gratitude to the Faculty of Pharmacy, Universitas Muslim Nusantara Al Washliyah, Medan, for providing research facilities and academic support during the implementation of this study. The authors also acknowledge the assistance of laboratory staff and all parties who contributed to the completion of the research process and manuscript preparation.

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