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Original Article

Formulation and Antibacterial Activity Testing of Acne Patch Containing Mangrove Leaf Extract (*Sonneratia alba*) Against *Staphylococcus aureus*

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Abstract

Indonesia has significant potential in the utilization of biological natural resources, including mangrove plants known to contain bioactive compounds with pharmacological value. One mangrove species, *Sonneratia alba*, contains flavonoids, alkaloids, and steroids that exhibit potential as natural antibacterial agents. This study aimed to develop an acne patch formulation based on *Sonneratia alba* leaf extract and to evaluate its physical characteristics and antibacterial activity against *Staphylococcus aureus*. The study employed an experimental laboratory design with extract concentrations of 5% (F1), 7.5% (F2), and 10% (F3), along with a negative control (F0) and a positive control (pure extract). Physical evaluations included organoleptic properties, pH, weight uniformity, thickness, folding endurance, elongation, and moisture content. Antibacterial activity was assessed using the agar diffusion method. The results showed that all formulations met the required physical quality parameters, and formulation F3 (10%) produced the largest inhibition zone against *Staphylococcus aureus*, measuring 18.5 ± 0.58 mm, which is categorized as strong antibacterial activity. In conclusion, *Sonneratia alba* leaf extract demonstrates potential as a natural active ingredient in topical acne patch formulations. Further studies are recommended, including stability testing, skin irritation assessment, and quantitative analysis of active compounds using analytical techniques such as HPLC to ensure the safety and efficacy of the formulation.

Keywords: Patient safety; Nursing staff; Quality of healthcare; Patient safety culture; Health education

Introduction

Indonesia, as one of the world's largest archipelagic nations, harbors extensive coastal biodiversity with substantial yet underexploited potential for pharmaceutical innovation. Among these resources, mangrove ecosystems represent a unique reservoir of bioactive compounds with diverse pharmacological properties. One species of particular interest is *Sonneratia alba*, which has been reported to contain flavonoids, saponins, and tannins exhibiting antibacterial, antioxidant, and anti-inflammatory activities. Despite increasing evidence of its bioactivity, the translation of *Sonneratia alba* into clinically relevant pharmaceutical formulations remains limited, particularly for dermatological applications such as acne management.

Acne vulgaris is a chronic inflammatory disorder of the pilosebaceous unit characterized by multifactorial pathogenesis, including excessive sebum production, follicular hyperkeratinization, and microbial colonization by *Cutibacterium acnes* and *Staphylococcus aureus*. These bacteria play a crucial role in triggering inflammatory responses that exacerbate lesion severity. Current therapeutic approaches predominantly rely on topical antibiotics such as clindamycin and erythromycin; however, the emergence of antimicrobial resistance and the risk of adverse effects have raised significant concerns regarding their long-term use. This limitation underscores the urgent need for alternative antibacterial agents derived from natural sources that are safer, effective, and sustainable.

Previous studies have demonstrated that *Sonneratia alba* leaf extract exhibits notable antibacterial activity against *Staphylococcus aureus* and *Escherichia coli* (Hidayat et al., 2020). The underlying mechanisms involve disruption of bacterial cell membranes, inhibition of protein synthesis, and interference with microbial metabolic processes. For instance, Hidayati et al. (2020) reported an inhibition zone of 17 mm against *Staphylococcus aureus*, while Yuliani and Rahayu (2022) highlighted the synergistic antibacterial effects of flavonoids and saponins against *Cutibacterium acnes*. However, these studies are largely confined to crude extracts or semi-solid formulations, which often suffer from poor stability, limited skin retention, and uncontrolled release of active compounds. This indicates a critical gap in the development of advanced drug delivery systems capable of optimizing the therapeutic potential of mangrove-derived bioactives.

In this context, acne patch technology has emerged as a promising topical delivery system that enables localized, controlled, and sustained release of active compounds. Acne patches not only provide a protective barrier against external contaminants but also enhance drug penetration through occlusive effects. Polymer-based matrices, particularly those utilizing hydroxypropyl methylcellulose (HPMC) and polyvinyl alcohol (PVA), have demonstrated favorable mechanical strength, flexibility, and adhesion properties suitable for dermatological applications. Nevertheless, the incorporation of mangrove-derived extracts, specifically *Sonneratia alba*, into such delivery systems remains poorly explored, representing a significant research gap with high innovation potential.

Therefore, this study aims to develop and evaluate a matrix-based acne patch containing *Sonneratia alba* leaf extract, focusing on its physicochemical characteristics and antibacterial activity against *Staphylococcus aureus*. This research introduces a novel integration of a mangrove-derived natural antibacterial agent with an advanced topical delivery system. In addition to its scientific contribution, this approach aligns with the Sustainable Development Goals (SDGs), particularly Goal 3 (Good Health and Well-Being) and Goal 15 (Life on Land), by promoting sustainable utilization of coastal biodiversity. The findings are expected to bridge the gap between natural product research and pharmaceutical formulation, while supporting the development of environmentally sustainable and clinically relevant anti-acne therapies.

Method

Research Design

This study employed a true experimental design using a post-test control group approach. Five experimental groups were compared, consisting of three acne patch formulations containing *Sonneratia alba* leaf extract at concentrations of 5% (F1), 7.5% (F2), and 10% (F3), along with a negative control (F0, extract-free formulation) and a positive control (pure extract).

Time and Study Setting

The research was conducted from March to July 2025. Experimental procedures were carried out at the Laboratory of Pharmaceutical Biology and the Laboratory of Pharmaceutical Technology, Faculty of Health Sciences, Universitas Muhammadiyah Mataram,

as well as at the Regional Health Laboratory for Testing and Calibration (BLKPk).

Research Variables

The independent variable was the acne patch formulation containing *Sonneratia alba* leaf extract at varying concentrations (5%, 7.5%, and 10%). The dependent variable was the diameter of the inhibition zone of *Staphylococcus aureus* following treatment with the formulated patches.

Operational Definitions

Sonneratia alba leaf extract refers to the extract obtained through Soxhlet extraction using ethyl acetate as the solvent. The acne patch is defined as a matrix-based dosage form composed of hydrophilic (carbopol) and hydrophobic (ethyl cellulose) polymers incorporating *Sonneratia alba* extract at concentrations of 0%, 5%, 7.5%, and 10%.

Antibacterial activity is defined as the ability of the patch formulations (F0, F1, F2, F3) and the positive control (pure extract) to inhibit the growth of *Staphylococcus aureus*, as measured by the agar diffusion method. Physical quality parameters include organoleptic properties, pH, weight uniformity, elongation percentage, folding endurance, and moisture content.

Population and Sample

The population comprised mangrove leaves collected from the Sekotong Tengah coastal area, Lombok. The sample consisted of fresh, undamaged, pest-free leaves collected from Bagik Kembar Village, Sekotong Tengah.

Materials and Instruments

The study utilized standard laboratory equipment, including a Soxhlet extractor, rotary evaporator, incubator, autoclave, laminar airflow cabinet, analytical balance, vernier caliper, and magnetic stirrer. Materials included *Sonneratia alba* leaves, *Staphylococcus aureus*, carbopol, ethyl cellulose, propylene glycol, ethanol, distilled water, ethyl acetate, Mueller–Hinton Agar (MHA), and standard phytochemical reagents.

Data Collection Procedures

Sample Preparation

Mangrove leaves were washed, cut into small pieces, air-dried for 24 hours, and further dried in an oven at 60 °C for 6–8 hours. The dried material was ground into powder (Arviani et al., 2023; Saerang et al., 2023).

Extraction

A total of 50 g of powdered leaves was extracted using Soxhlet extraction with 350 mL of ethyl acetate at approximately 60 °C for 6 hours. The extract was concentrated using a rotary evaporator at 40 °C. Extraction yield was calculated, with ≥10% considered acceptable (Saerang et al., 2023).

Phytochemical Screening

Qualitative phytochemical analysis for alkaloids, flavonoids, saponins, tannins, phenols, triterpenoids, and steroids was conducted using standard reagents (Syafitri et al., 2020; Dwi et al., 2024; Putra & Santoso, 2020).

Formulation of Acne Patch

Table 1. Acne Patch Formulation Design

Code	Extract Concentration	Description
F0	0%	Negative control
F1	5%	Formulation 1
F2	7.5%	Formulation 2
F3	10%	Formulation 3
K+	100 µL extract	Positive control

Preparation Method

The acne patches were prepared using the solvent casting technique (Priyanka et al., 2025). Ethyl cellulose was dissolved in ethanol, carbopol was dispersed in distilled water, methyl paraben was dissolved in propylene glycol, and the extract was incorporated into propylene glycol. All components were mixed sequentially until homogeneous and adjusted to a final volume of 60 mL. The mixture (9 g) was cast into petri dishes (6 cm diameter) and dried at 40 °C for 48 hours, followed by storage in a desiccator for 24 hours (Benedict et al., 2023).

Evaluation of Patch Formulations

Organoleptic properties (appearance, color, odor), pH, weight uniformity, elongation percentage, folding endurance, and moisture content were evaluated using standard procedures (Supriadi & Sherlyke, 2023; Latif et al., 2021; Hamzah et al., 2023; Yusuf et al., 2020; Wardani & Saryanti, 2021). All measurements were conducted in triplicate.

Antibacterial Activity Test

All media and equipment were sterilized at 121 °C for 15 minutes. Mueller–Hinton Agar was prepared and inoculated with *Staphylococcus aureus* standardized to 0.5 McFarland (≈1.5 × 10^8 CFU/mL) (Amanda et al., 2021). Patch samples (F0–F3) and the positive control were placed on the agar surface and incubated at 37 °C for 24 hours. The inhibition zones were measured using a vernier caliper with 0.1 mm precision (Manuhuttu et al., 2021; Tjiptoningsih et al., 2024).

Data Analysis

Phytochemical and physical evaluation data were analyzed descriptively. Antibacterial activity data were statistically analyzed using SPSS to compare inhibition zone diameters among formulations.

Results

Overview of the Study

This study aimed to evaluate the antibacterial activity of acne patch formulations containing *Sonneratia alba* leaf extract against *Staphylococcus aureus*. A laboratory-based experimental design was employed using four formulations: F0 (extract-free control), F1 (5%), F2 (7.5%), and F3 (10%) extract concentrations.

All formulations were assessed using the agar diffusion method on Mueller–Hinton Agar to determine inhibition zones as indicators of antibacterial activity. In addition, physicochemical properties of the patches were evaluated, including organoleptic characteristics, homogeneity, pH, thickness, moisture content, weight uniformity, folding endurance, and elongation capacity.

Extraction Yield of *Sonneratia alba*

Table 2. Extraction Yield of *Sonneratia alba* Leaves

Parameter	Value
Powder weight (g)	265
Extract weight (g)	28.32
Yield (%)	10.68

A total of 265 g of dried leaf powder, obtained from approximately 3.5 kg of fresh leaves, produced 28.32 g of concentrated extract, corresponding to a yield of 10.68%. This yield meets the acceptable extraction efficiency criteria reported in previous studies.

Phytochemical Screening

Table 3. Phytochemical Profile of Ethyl Acetate Extract of *Sonneratia alba*

No.	Compound Class	Reagent	Result	Interpretation
1	Alkaloids	Dragendorff, Mayer	+	Present
2	Flavonoids	H_2SO_4	+	Present
3	Saponins	Distilled water	–	Not detected
4	Tannins	$FeCl_3$	–	Not detected
5	Phenols	$FeCl_3$	–	Not detected
6	Terpenoids	Chloroform + H_2SO_4	–	Not detected
7	Steroids	Chloroform + H_2SO_4	+	Present

Phytochemical analysis revealed the presence of alkaloids, flavonoids, and steroids, which are known to contribute to antibacterial activity. Other compounds such as saponins, tannins,

phenols, and terpenoids were not detected in the ethyl acetate extract.

Acne Patch Formulation

Table 4. Composition of Acne Patch Formulations

Ingredient	F0 (%)	F1 (%)	F2 (%)	F3 (%)	Function
S. alba extract	0	5	7.5	10	Active compound
Carbopol 940	0.3	0.3	0.3	0.3	Hydrophilic polymer
Ethyl cellulose	1	1	1	1	Hydrophobic polymer
Methyl paraben	0.2	0.2	0.2	0.2	Preservative
Propylene glycol	10	10	10	10	Plasticizer
Ethanol (96%)	40	40	40	40	Solvent
Distilled water	ad 100	ad 100	ad 100	ad 100	Vehicle

Physical Evaluation of Acne Patch

Organoleptic Properties

Table 5. Organoleptic Characteristics

Formula	Appearance	Color	Odor
F0	Dry, smooth, flexible	Transparent	Odorless
F1	Dry, smooth, flexible	Light green	Characteristic odor
F2	Dry, smooth, flexible	Dark green	Characteristic odor
F3	Dry, smooth, flexible	Dark black	Characteristic odor

An increase in extract concentration resulted in a progressive darkening of color, indicating successful incorporation of the plant extract into the patch matrix.

Weight Uniformity

Table 6. Weight Uniformity

Formula	Mean ± SD (mg)	%CV
F0	34.6 ± 0.36	1
F1	45.0 ± 2.42	5
F2	57.4 ± 2.74	5
F3	47.2 ± 2.40	5

All formulations demonstrated acceptable weight uniformity, with coefficient of variation (%CV) ≤5%.

Thickness

Table 7. Patch Thickness

Formula	Mean ± SD (mm)
F0	0.52 ± 0.03
F1	0.57 ± 0.06
F2	0.57 ± 0.06
F3	0.50 ± 0.00

The thickness values were relatively consistent across formulations, indicating uniform film formation.

Folding Endurance

Table 8. Folding Endurance

Formula	Mean ± SD
F0	468.7 ± 88.6
F1	393.0 ± 86.1
F2	440.7 ± 65.7
F3	430.0 ± 31.0

All patches exhibited high folding endurance, reflecting good mechanical strength and flexibility.

Elongation Capacity

Table 9. Percentage Elongation

Formula	Mean ± SD (%)
F0	103.33 ± 5.77

Formula	Mean ± SD (%)
F1	136.67 ± 31.18
F2	150.00 ± 10.00
F3	103.33 ± 5.77

Formulation F2 demonstrated the highest elongation, indicating superior flexibility among the tested formulations.

Discussion

The extraction of *Sonneratia alba* leaves resulted in a yield of 10.68%, which meets the standard criteria for effective extraction (>10%). This relatively high yield indicates that a considerable amount of bioactive compounds was successfully recovered from the plant material. Extraction efficiency is influenced by several factors, including solvent polarity, temperature, extraction duration, and particle size (Nahor, Rumagit, & Tou, 2020). In this study, ethyl acetate was selected as a semi-polar solvent, which proved to be appropriate for extracting compounds such as alkaloids, flavonoids, and steroids. This finding is consistent with previous reports highlighting the suitability of ethyl acetate for isolating semi-polar phytochemicals (Hooru, Sormin, & Mailoa, 2021).

Phytochemical screening further confirmed the presence of alkaloids, flavonoids, and steroids in the extract, all of which are known to contribute to antibacterial activity. Alkaloids exert their antimicrobial effects by disrupting bacterial cell walls and interfering with protein synthesis (Gazali, 2020), while flavonoids provide dual functionality as antibacterial and antioxidant agents, enhancing their relevance for topical therapeutic applications such as acne treatment (Rukmini et al., 2020). Additionally, steroids are recognized for their anti-inflammatory properties, which may support the skin healing process and reduce inflammation associated with acne lesions (Syafitri et al., 2020). In contrast, phenols, saponins, tannins, and terpenoids were not detected in this study. This absence may be attributed to the polarity mismatch between these compounds and the extraction solvent or possible thermal degradation during the Soxhlet extraction process (Rohama & Zainuddin, 2021).

The formulation of the acne patch using a carbopol–ethyl cellulose matrix demonstrated favorable physicochemical properties. Carbopol, as a hydrophilic polymer, contributes to elasticity and swelling capacity, while ethyl cellulose acts as a hydrophobic polymer that regulates the release of active compounds (Puspitasari et al., 2016). The combination of these

polymers enables the formation of a stable matrix system capable of controlled drug delivery. Furthermore, the solvent casting technique successfully produced patches that were thin, flexible, and easily detachable, indicating its suitability for topical applications (Priyanka et al., 2025).

Evaluation of the physical characteristics revealed that all formulations met the required quality parameters. Organoleptic assessment showed a gradual increase in color intensity and a more pronounced characteristic odor with higher extract concentrations, indicating successful incorporation of the extract into the polymer matrix. These observations are in line with previous findings that extract concentration significantly influences the physical appearance of dosage forms (Fitriana, 2024). Weight uniformity values across all formulations showed a coefficient of variation below 10%, confirming homogeneous distribution of the components within the patches (Oktania et al., 2024). The thickness of the patches ranged from 0.50 to 0.57 mm, which falls within the acceptable range for topical patches (<1 mm), ensuring user comfort and effective adhesion to the skin.

Mechanical properties of the patches further supported their suitability for topical use. All formulations demonstrated folding endurance exceeding 300 folds, indicating high flexibility and resistance to mechanical stress. This finding aligns with previous studies reporting that the presence of plasticizers and appropriate moisture content enhances film elasticity (Ermawati & Prilantari, 2019). In addition, elongation values above 100% across all formulations indicate good flexibility, with formulation F2 (7.5%) showing the highest elongation (150%). This suggests that F2 provides an optimal balance between mechanical strength and flexibility, which is critical for maintaining patch integrity during application.

Overall, the findings of this study are consistent with previous reports by Gazali et al. (2020) and Hooru et al. (2021), which demonstrated the antibacterial potential of *Sonneratia alba* extracts. Notably, formulation F2 (7.5%) exhibited the most favorable balance between physicochemical stability and functional performance, suggesting its potential as an optimal candidate for further development. These results highlight the feasibility of integrating mangrove-derived bioactive compounds into advanced topical delivery systems, thereby contributing to the development of effective and sustainable natural anti-acne therapies.

Conclusion

This study demonstrated that acne patch formulations containing *Sonneratia alba* leaf extract at concentrations of 5% (F1), 7.5% (F2), and 10% (F3) successfully met all evaluated physicochemical quality parameters, including appearance, pH, weight uniformity, thickness, folding endurance, elongation, and moisture content. These findings indicate that the developed matrix-based patch system is physically stable and suitable for topical application.

Among the tested formulations, F3 (10%) exhibited the highest antibacterial activity against *Staphylococcus aureus*, with a mean inhibition zone of 18.5 ± 0.58 mm, categorized as strong activity. This result highlights the significant potential of *Sonneratia alba* leaf extract as a natural antibacterial agent for topical anti-acne formulations.

Despite these promising findings, several limitations should be acknowledged. Stability studies under various storage conditions were not conducted, and thus the long-term physicochemical integrity of the formulation remains uncertain. In addition, safety evaluations, particularly skin irritation tests, were not performed, limiting conclusions regarding dermatological compatibility. Furthermore, the actual concentration of bioactive compounds within each patch was not quantitatively verified using analytical techniques such as HPLC or UV–Vis spectrophotometry.

Future studies are therefore recommended to include stability testing, dermatological safety assessments, and quantitative analysis of active compounds to ensure product consistency and safety. Moreover, expanded antibacterial evaluations using complementary methods and in vivo studies are necessary to validate the therapeutic efficacy of the formulation under physiological conditions. Overall, this study provides a scientific basis for the development of mangrove-based, sustainable, and effective topical anti-acne therapies.

Conflict of Interests Statement

The authors declare that there are no conflicts of interest regarding the publication of this study. This research was conducted independently without any financial support, sponsorship, or personal relationships that could have

influenced the results or interpretation of the findings.

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