

# Antibacterial activity of *musa balbisiana* peel extract against diabetic ulcer pathogens

Diyah Candra Anita<sup>1\*</sup>, Arif Yusuf Wicaksana<sup>2</sup>, Ratna Wijayatri<sup>3</sup>, and Khoiriyah Khoiriyah<sup>4</sup>

<sup>1</sup>Study Program of Nursing, Faculty of Health Science, Universitas Aisyiyah Yogyakarta, Yogyakarta, Indonesia

<sup>2</sup>Study Program of Medical Laboratory Technology, Faculty of Health Science, Universitas Aisyiyah Yogyakarta, Yogyakarta, Indonesia

<sup>3</sup>Study Program of Pharmacy, Faculty of Health Science, Universitas Muhammadiyah Magelang, Center Java, Indonesia

<sup>4</sup>Study Program of Nursing Department, Faculty of Nursing and Health Science, Universitas Muhammadiyah Semarang, Center Java, Indonesia

**Abstract.** Banana peel (*Musa balbisiana*) contains bioactive compounds with potential antimicrobial activity that may support diabetic ulcer management. This study aimed to evaluate the antibacterial activity of banana peel extracts and their cream formulations against ulcer-associated pathogens. Fresh and waste banana peel extracts were prepared using ethanol and methanol solvents, and phytochemical screening was performed. Antibacterial activity was tested against *Staphylococcus aureus*, *Staphylococcus epidermidis*, and *Pseudomonas aeruginosa* using minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC), and disc diffusion assays. Cream formulations containing 1-4% extracts were also evaluated for physical characteristics. The results showed banana peel extracts contained alkaloids, flavonoids, tannins, and saponins. The MIC was observed at 4% and MBC at 10%, with more vigorous activity against Gram-positive bacteria (*S. aureus*, *S. epidermidis*) than Gram-negative (*P. aeruginosa*). Methanol extracts exhibited higher activity compared to ethanol extracts. Cream formulations demonstrated acceptable spread ability (5.5-7.0 cm), adhesion (1.5-2.7 s), and skin-compatible pH (5.0-6.0). These findings suggest that banana peel extracts possess promising antibacterial potential and can be developed into topical formulations for diabetic ulcer management. Further in vivo and clinical studies are needed to validate efficacy.<sup>1</sup>

## 1 Introduction

Diabetic foot ulcers are among the most serious chronic complications of diabetes mellitus, with a high risk of bacterial infection that can delay wound healing and increase the likelihood of amputation [1]. Common bacterial pathogens involved include *Staphylococcus aureus*, *Staphylococcus epidermidis*, and *Pseudomonas aeruginosa*, all of which have demonstrated growing resistance to conventional antibiotics [2]. This escalating resistance

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\*Corresponding author: [diyah.candra@unisayogya.ac.id](mailto:diyah.candra@unisayogya.ac.id)

crisis underscores the urgency of exploring natural products as alternative antibacterial agents that may support or substitute conventional therapies.

Banana (*Musa spp.*) peel is an agricultural byproduct often discarded as waste. Yet, several studies have reported its richness in bioactive compounds such as alkaloids, flavonoids, tannins, and saponins. These phytochemicals are known for their antimicrobial and antioxidant properties, suggesting that banana peel extract could be a potential natural antibacterial agent [3]. Specifically, the yellow kepok banana (*Musa balbisiana*), widely cultivated in Southeast Asia, has not been extensively studied for its biomedical applications, despite its abundance and low economic value as waste material.

Given this background, the present study aimed to evaluate the antibacterial activity of *Musa balbisiana* peel extract and develop a topical cream formulation as a potential therapeutic agent for diabetic ulcer infections. The rationale lies in transforming agricultural waste into value-added products while addressing a pressing medical need. Previous investigations on plant-derived topical formulations have demonstrated promising results in wound management by combining antimicrobial and antioxidant effects [4].

However, most studies have focused on other plant-derived compounds or different banana species, with limited evidence regarding the systematic evaluation of *Musa balbisiana* peel extract in both phytochemical characterization and cream formulation against clinically relevant diabetic ulcer pathogens. This gap highlights the novelty of the present research, which integrates phytochemical screening, antibacterial activity assessment, and topical formulation development.

Based on these considerations, it was hypothesized that *Musa balbisiana* peel extract contains active phytochemicals with antibacterial potential, and that its incorporation into a topical cream formulation would enhance its applicability as an adjunctive therapy for diabetic ulcers. This study, therefore, contributes to scientific evidence on natural antibacterial compounds and the practical development of waste-based pharmaceutical innovations.

## 2 Method

### 2.1 Research design

This study employed an experimental laboratory design with a quantitative approach to evaluate the antibacterial activity and topical cream formulation of *Musa balbisiana* (yellow kepok banana) peel extract. The research stages included sample preparation, extraction, phytochemical screening, antioxidant activity test, antibacterial assays, cream formulations, and physical evaluation of the cream.

### 2.2 Scope and study object

The study focused on banana peel waste derived from ripe *Musa balbisiana*, collected from local markets in Magelang, Central Java, Indonesia. The primary objects of analysis were (1) phytochemical compounds contained in the peel extract, (2) antibacterial activity against ulcer pathogens, and (3) the physical quality and antibacterial performance of the formulated cream.

### 2.3 Materials and equipment

The primary materials included dried *Musa balbisiana* peel powder, ethanol (96%), methanol, aquadest, and standard laboratory media for bacterial culture (*Nutrient Agar* and

*Nutrient Broth*). The bacterial strains used were *Staphylococcus aureus*, *Staphylococcus epidermidis*, and *Pseudomonas aeruginosa*, obtained from the Balai Laboratorium Kesehatan (BLK) Yogyakarta. Laboratory instruments consisted of an oven, water bath, rotary evaporator, spectrophotometer, UV-Vis, colony counter, incubator, analytic balance, pH meter, viscometer, and glassware.

## 2.4 Place and data source

Sample preparation and extraction were conducted at Universitas Muhammadiyah Magelang, while phytochemical screening and antibacterial tests were carried out at Universitas Ahmad Dahlan and BLK Yogyakarta. The study used both primary data (experimental results) and secondary data (from relevant scientific literature).

## 2.5 Data collection techniques

The research began with the extraction of dried *Musa balbisiana* peel powder using ethanol and methanol through maceration, followed by concentration with a rotary evaporator. Using UV-Vis spectrophotometry and qualitative tests, phytochemical screening was performed to identify alkaloids, flavonoids, tannins, saponins, and antioxidant activity. Antibacterial assays were carried out through dilution methods to determine the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC), while disc diffusion was used to evaluate inhibition zones against *S. aureus*, *S. epidermidis*, and *P. aeruginosa*. Extracts were then formulated into oil-in-water cream bases at different concentrations and tested for physical quality parameters, including organoleptic properties, homogeneity, viscosity, spread ability, adhesion, and pH, to ensure compliance with topical preparation standards [4].

## 2.6 Operational definition of variables

In this study, the independent variable was the type of extract obtained from *Musa balbisiana* peel, specifically ethanol and methanol extracts, applied in various concentrations. The dependent variables consisted of antibacterial effectiveness, expressed through inhibition zone diameters, MIC, and MBC, as well as the physical quality of the cream formulations, including pH, viscosity, spread ability, adhesion, and homogeneity. To ensure consistency, several controlled variables were maintained, such as incubation condition at 37°C for 24 hours, standardized bacterial inoculum equivalent to McFarland 0.5, and uniform cream base composition across all formulations.

## 2.7 Data analysis

Experimental data were analyzed descriptively and quantitatively. Phytochemical contents were expressed as mean  $\pm$  SD of triplicate measurements. The lowest concentration determined MIC and MBC values, which showed visible inhibition or bactericidal effect. Antibacterial activity from diffusion assays was expressed as mean inhibition zone diameters, compared with standard antibiotics (gentamicin and chloramphenicol) as positive controls. Physical parameters of cream formulation were evaluated against pharmacopeia standards for topical preparations.

### 3 Results and discussion

The findings of this study are presented in two integrated parts: the experimental results and their scientific interpretation. Results include phytochemical characterization of *Musa balbisiana* peel extract, antioxidant capacity, antibacterial assays against ulcer-associated pathogens, and the evaluation of cream formulations developed from the extracts. To provide a comprehensive understanding, the discussion highlights the relevance of these findings to previous literature, explores the underlying mechanisms of antibacterial and antioxidant activity, and examines the practical implications of incorporating banana peel extract into topical preparations for diabetic ulcer management.

#### 3.1 Phytochemical screening and antioxidant activity

**Table 1.** Phytochemical content of *musa balbisiana* peel extracts

| Compound   | MeOH Fresh (ppm) | EtOH Fresh (ppm) | EtOH Waste (ppm) |
|------------|------------------|------------------|------------------|
| Alkaloids  | 391.65 ± 1.60    | 149.70 ± 1.04    | 98.53 ± 1.04     |
| Flavonoids | 14.28 ± 0.19     | 7.40 ± 0.12      | 11.59 ± 0.19     |
| Tannins    | 33.59 ± 0.11     | 67.43 ± 0.21     | 96.70 ± 0.21     |
| DPPH (%)   | 536.00 ± 1.41    | 1.43 ± 0.01      | 0.00 ± 0.01      |
| Saponins   | +                | +                | +                |

Phytochemical analysis revealed the presence of alkaloids, flavonoids, tannins, and saponins in both ethanol and methanol extracts of *Musa balbisiana* peel. Quantitative determination indicated higher alkaloid content in methanol extracts (391.65 ppm) compared to ethanol extracts (149.70 ppm fresh peel and 98.53 ppm peel waste). Flavonoid and tannin contents also varied, with tannins most abundant in ethanol waste extracts (96.70 ppm). Antioxidant activity (DPPH assay) demonstrated more vigorous activity in methanol extracts compared to ethanol. Saponins were identified qualitatively through the froth test due to the absence of a standardized spectrophotometric method for their quantification; nevertheless, their positive presence indicates potential antibacterial contribution alongside other phytochemicals (Table 1).

The results confirmed that *Musa balbisiana* peel is rich in bioactive compounds with known antibacterial and antioxidant potential [5]. Each of these compounds has been widely associated with antimicrobial activity. Alkaloids, for example, can disrupt bacterial DNA synthesis and impair protein expression, leading to bacterial effects [6]. Flavonoids inhibit nucleic acid synthesis and disrupt bacterial membranes, while tannins precipitate proteins and inhibit enzymes essential for bacterial survival. Saponins, though primarily known for their surfactant properties, can increase membrane permeability and facilitate the penetration of other bioactive compounds. The synergy of these phytochemicals may explain the consistent antibacterial activity observed in extract and cream formulations.

#### 3.2 Minimum inhibitory and bactericidal concentrations

The MIC test using the dilution method showed that banana peel extracts could inhibit bacterial growth at 4% concentration across all tested strains (*S. aureus*, *S. epidermidis*, and *P. aeruginosa*). The MBC varied depending on the bacterial strain and type of extract. Methanol extract of fresh peels demonstrated the most potent bactericidal effect, while ethanol-waste extracts generally showed weaker activity. At 10% concentration, the methanol extract successfully reduced the colony counts to the lowest measurable level, particularly against *S. aureus* and *S. epidermidis* (Table 2).

**Table 2.** Summary of MBC results of banana peel extracts

| Bacteria              | Extract Type | 2%          | 4%          | 10%         | Notes                          |
|-----------------------|--------------|-------------|-------------|-------------|--------------------------------|
| <i>P. aeruginosa</i>  | MeOH-fresh   | 193 cfu     | Uncountable | 225 cfu     | Weak effect, no complete kill  |
|                       | EtOH-fresh   | Uncountable | Uncountable | Uncountable | Low activity                   |
|                       | EtOH-waste   | Uncountable | Uncountable | Uncountable | Low activity                   |
| <i>S. aureus</i>      | MeOH-fresh   | Uncountable | 36 cfu      | 114 cfu     | Stronger than ethanol extracts |
|                       | EtOH-fresh   | Uncountable | Uncountable | 102 cfu     | Limited effect                 |
|                       | EtOH-waste   | Uncountable | Uncountable | Uncountable | Ineffective                    |
| <i>S. epidermidis</i> | MeOH-fresh   | 13 cfu      | Uncountable | 8 cfu       | Best activity                  |
|                       | EtOH-fresh   | 137 cfu     | 42 cfu      | 40 cfu      | Moderate effect                |
|                       | EtOH-waste   | Uncountable | Uncountable | Uncountable | Ineffective                    |

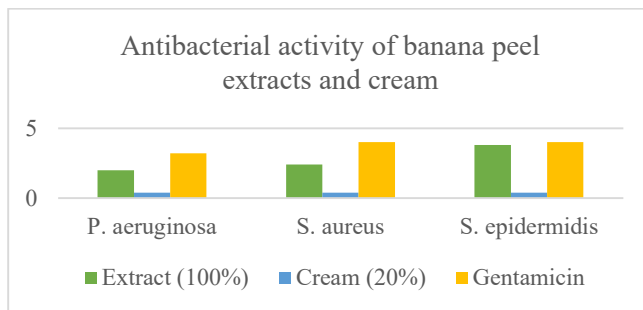
The MIC value of 4% indicates that banana peel extracts effectively inhibit bacterial growth, though bactericidal activity requires higher concentrations. The superior activity of methanol extracts compared to ethanol extracts can be attributed to differences in solvent polarity, affecting phytochemical extraction efficiency. Alkaloids, flavonoids, and tannins, abundant in methanol extract, are known to disrupt bacterial membranes, precipitate proteins, and inhibit enzymatic. *S. epidermidis* showed the highest susceptibility among the tested bacteria, as indicated by low colony counts at 10% methanol extract. This is consistent with previous studies demonstrating that Gram-positive bacteria are often more susceptible to plant-derived antimicrobials than Gram-negative bacteria, due to the absence of an outer membrane that can act as a permeability barrier [7]. Interestingly, ethanol-waste extracts consistently displayed poor antibacterial activity. This may be due to degradation of bioactive compounds during storage and handling of the raw peels, as phytochemicals such as flavonoids are sensitive to oxidation and thermal stress [8]. These findings emphasize the importance of biomass quality in determining extract potency. These results highlight that banana peel extracts, particularly methanol fresh peel extracts, possess promising bactericidal properties against diabetic ulcer-associated pathogens. Their MIC and MBC values suggest potential as an alternative or complementary topical antimicrobial, especially in the context of increasing antibiotic resistance [9].

### 3.3 Antibacterial activity by disc diffusion

The disc diffusion method evaluated the antibacterial activity of banana peel extracts and cream formulations. Extracts at concentrations below 20% did not produce measurable inhibition zones. Noticeable antibacterial activity appeared at 20-100% concentrations, with inhibition zones ranging from 0.2 to 3.2 cm depending on bacterial strain and extract type.

For *P. aeruginosa*, inhibition zones appeared at concentrations of 20% and above, with the largest diameters reaching 2.0 cm at 100% methanol and ethanol extracts. Cream formulations produced only weak inhibition (0.2-0.4 cm), while gentamicin (control) produced consistently larger zones of inhibition (2.6-3.2 cm). For *S. aureus*, the extracts showed more potent activity compared to *P. aeruginosa*. At 50-100% concentrations, inhibition zones reached 2.0-2.4 cm. Cream formulations at 20% maintained moderate activity (0.2-0.4 cm). Gentamicin controls exhibited uniform zones of 4.0 cm, much higher than the extracts. For *S. epidermidis*, the extracts demonstrated the most potent antibacterial effect among the tested strains. Methanol extracts at 100% concentration yielded inhibition zones up to 3.2 cm, which approached the inhibition of gentamicin (3.8-4.0 cm). Cream formulations retained measurable though smaller activity (0.2-0.4 cm). Overall, the antibacterial activity of the extracts followed the pattern: *S. epidermidis* > *S. aureus* > *P.*

*aeruginosa*, with methanol extracts showing superior activity compared to ethanol extracts and cream formulations displaying reduced but consistent inhibitory effects (Fig.1).



**Fig. 1.** Antibacterial activity of banana peel extract and cream

The disc diffusion assay confirmed that banana peel extracts exhibit dose-dependent antibacterial activity, with higher concentrations ( $\geq 50\%$ ) producing a zone comparable to moderate synthetic antibiotics. The methanol extracts consistently showed better inhibition than ethanol extracts, supporting previous findings that solvent polarity significantly affects the recovery of bioactive compounds [10]. The activity against *S. aureus* and *S. epidermidis* was stronger than against *P. aeruginosa*. This is consistent with the intrinsic resistance of Gram-negative bacteria such as *P. aeruginosa*, which possess an outer membrane that restricts penetration of hydrophobic phytochemicals. Conversely, Gram-positive bacteria are generally susceptible due to the absence of this barrier. Cream formulations retained antibacterial activity, albeit weaker than crude extracts. This reduction may be attributed to diffusion limitations of active compounds within the cream matrix. Nonetheless, maintaining activity in topical form is significant, as it demonstrates the feasibility of developing banana peel-based creams as adjunct wound-care products. Importantly, inhibition zones of extracts at high concentrations approached those of gentamicin against *S. epidermidis*. This suggests potential utility in managing diabetic ulcer infections, particularly where antibiotic resistance is prevalent [11].

### 3.4 Cream formulation and physical evaluation

Banana peel extracts were incorporated into cream formulations at concentrations of 1%, 2%, and 4%. The base cream consisted of stearic acid, cetyl alcohol, triethanolamine (TEA), glycerin, preservatives (nipagin, nipasol), and DMDM hydantoin as an antifoaming agent. The detailed composition is shown in Table 3.

**Table 3.** Composition of banana peel extract cream formulations

| Ingredients           | F0 (control, %) | F1 (1%) | F2 (2%) | F3 (4%) | Function     |
|-----------------------|-----------------|---------|---------|---------|--------------|
| Banana peel extract   | 0               | 1       | 2       | 4       | Active agent |
| Stearic acid          | 12              | 12      | 12      | 12      | Emulsifier   |
| Cetyl alcohol         | 1               | 1       | 1       | 1       | Thickener    |
| Triethanolamine (TEA) | 1               | 1       | 1       | 1       | Emulsifier   |
| Glycerin              | 2               | 2       | 2       | 2       | Humectant    |
| Nipagin               | 0.1             | 0.1     | 0.1     | 0.1     | Preservative |
| Nipasol               | 0.05            | 0.05    | 0.05    | 0.05    | Preservative |
| DMDM hydantoin        | 0.05            | 0.05    | 0.05    | 0.05    | Antifoaming  |
| Aquadest.             | Ad 100          | Ad 100  | Ad 100  | Ad 100  | Solvent      |

The creams underwent physical evaluation tests, including organoleptic assessment, homogeneity, spread ability, adhesion, and pH. All formulations displayed acceptable physical stability. The results are summarized in Table 4.

**Table 4.** Physical evaluation of banana peel extract creams

| Test Parameter          | Observation/Results   | Interpretation                      |
|-------------------------|---|-------------------------------------|
| Organoleptic            | Color : white-brownish<br>Odor : banana-like aroma (stronger with higher conc)<br>Texture : thick and uniform | Acceptable for topical use          |
| Homogeneity             | All formulations with DMDM hydantoin showed no coarse particles   | Homogeneous                         |
| Spread ability          | 5.5-7.0 cm depending on formulation   | Within an acceptable range (5-7 cm) |
| Adhesion                | 1.5-2.7 s; lower for 4-10% fresh extract creams, higher for waste extract creams                              | Adequate adhesion                   |
| pH                      | 5.0-6.0 for extract creams; 7.0 for base cream  | Suitable for skin (pH 4.5-6.5)      |
| Microbial contamination | Low; highest in waste-extract creams but still below pharmacopeial limits                                     | Safe for cosmetic application       |

The successful incorporation of banana peel extract into cream formulations demonstrates its feasibility as a topical antimicrobial preparation. The physical evaluation confirmed that the creams met standard topical formulation requirements, including spread ability (5-7 cm) and skin-compatible pH (5-6). Adding DMDM hydantoin improved cream texture and eliminated foaming, resulting in stable, homogenous preparations (Table 4).

Organoleptic variations with increasing extract concentration (darker color, more pungent odor) reflect the higher phytochemical content expected in natural product-based formulations [12]. Spread ability and adhesion results indicate that the creams can be easily applied and maintained on the skin, which is critical for wound care applications [13]. Although microbial contamination was detected, all values remained below pharmacopeial thresholds, supporting the safety of the formulations. However, stricter processing is recommended when using waste-derived raw materials, as they carry higher microbial loads. Overall, the formulated creams showed stable physicochemical characteristics and skin-compatible pH, and they maintained the antibacterial potential of banana peel extracts, highlighting their promise as a low-cost, plant-based topical therapeutic option.

### 3.5 Implications for diabetic ulcer management and future research

Based on the antibacterial activity against *S. aureus*, *S. epidermidis*, and *P. aeruginosa*, and the successful formulation into stable topical creams, banana peel extracts demonstrate promising potential for diabetic ulcer management. The implications of these findings are summarized in Table 5.

**Table 5.** Implications of banana peel extract findings for diabetic ulcer management

| Key Finding   | Implications for Diabetic Ulcers                                    | Future Research Direction  |
|---|---|--|
| High phytochemical content (alkaloids, flavonoids, tannins, antioxidants, saponins) | Supports wound healing via antimicrobial and antioxidant mechanisms | Isolation and characterization of active compounds                 |
| MIC at 4% and MBC effective at 10% (especially methanol extracts)                   | Potential as an alternative antimicrobial agent for ulcer pathogens | Standardized dose-response and synergetic studies with antibiotics |

| Key Finding   | Implications for Diabetic Ulcers   | Future Research Direction                               |
|---|--|---|
| More potent inhibition against Gram-positive ( <i>S. aureus</i> , <i>S. epidermidis</i> ) than Gram-negative ( <i>P. aeruginosa</i> ) | Beneficial in targeting common Gram-positive infections in diabetic ulcers | Formulation optimizing for Gram-negative coverage       |
| Cream formulation (1-4%) with acceptable spread ability, adhesion, and pH 5-6   | Suitable for topical application, compatible with skin barrier             | Stability studies and in vivo wound healing assays      |
| Microbial contamination is low but higher in waste-derived extracts   | Feasible to valorize agro-waste with additional sterilization steps        | Advanced purification and green processing technologies |

The findings suggest that banana peel extracts can be a low-cost, natural antimicrobial adjunct for managing diabetic ulcers (Table 5). Bioactive compounds such as alkaloids and flavonoids contribute to antibacterial and antioxidant activities, necessary in chronic wound environments where oxidative stress delays healing [4]. The demonstrated activity against *S. aureus* and *S. epidermidis* is particularly relevant, since these Gram-positive bacteria are major contributors to infected diabetic foot ulcers [1]. Although activity against *P. aeruginosa* was weaker, the potential to use extracts in combination with standard antibiotics may enhance treatment efficacy and reduce resistance risk [14]. The creams displayed acceptable physicochemical parameters and skin-compatible pH from a formulation standpoint, underscoring their practicality for topical use [13]. However, further evaluation in animal wound models and controlled clinical studies will be essential to confirm safety and therapeutic effectiveness. Future research should address scalability, stability, and regulatory considerations for herbal-based topical preparations. Valorizing banana peel waste as a therapeutic product supports sustainable healthcare solutions and contributes to circular economy strategies in agricultural byproduct utilization [15].

### 3.6 Limitations of the study

This study was limited to in vitro assays using disc diffusion and dilution methods, which may not fully represent the complex physiological environment of diabetic wounds. Only selected bacterial strains were tested; no in vivo or clinical validation was conducted. Additionally, using agro-waste extracts introduced variability in phytochemical content and microbial contamination risk, which may affect the reproducibility and scalability of the formulations.

## 4 Conclusion

Banana peel extracts demonstrated significant antibacterial activity, particularly against Gram-positive pathogens associated with diabetic ulcers. Methanol extracts were more effective, with MIC at 4% and MBC at 10%. Cream formulations retained acceptable physical properties and skin-compatible pH, supporting their potential as low-cost, plant-based topical preparations. Further in vivo and clinical validation is required before therapeutic application

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