BIOLOGY, MEDICINE, & NATURAL PRODUCT CHEMISTRY ISSN 2089-6514 (paper)
Volume 15, Number 2, October 2026 | Pages: 2203-2211 | DOI: 10.14421/biomedich.2026.152.2203-2211 ISSN 2540-9328 (online)

Antibacterial of *Eugenia uniflora* Extract Emulgel Formulation Against *Staphylococcus aureus*

Desy Muliana Wenas[1]*, Diny Aulia Mawarni[1], Herdini[2]
[1]Biology Pharmacy Department, Faculty of Pharmacy; [2]Phytochemistry Department,Faculty of Pharmacy,
Institut Sains dan Teknologi Nasional,
Jl. Moh Kahfi II, Srengseng Sawah, Jakarta 12640, Tel. +62-21-7874645, Indonesia.

Corresponding author*
desywenas@istn.ac.id

Manuscript received: 14 August 2026. Revision accepted: 10 November 2026, Published: 19 November 2026.

Abstract

Body odor is a common condition caused by bacterial activity on the skin surface, especially *Staphylococcus aureus*, which breaks down sweat components, producing an unpleasant odor. The use of synthetic deodorants has the potential to cause irritation and raises concerns about long-term safety, so safe and effective natural alternatives are needed. Dewandaru leaves (*Eugenia uniflora* L.) are known to contain active compounds that have antibacterial potential and can be developed into a mild, easy-to-apply, and stable emulgel preparation. This study aimed to formulate dewandaru leaf extract with various concentrations in an emulgel deodorant preparation and test its antibacterial activity against *Staphylococcus aureus*. Three formulas were prepared, namely F0 (blank), F1 (5% extract), and F2 (10% extract). Evaluation of the quality of the preparation includes organoleptic tests, homogeneity, pH, viscosity and flow properties, spreadability, adhesiveness, emulsion type, and stability using the cycling test method. Antibacterial activity test was conducted using the well diffusion method using chloramphenicol as a positive control and 10% DMSO as a negative control. The results showed that all formulas had good physical stability before and after the cycling test, indicated by no changes in shape, color, aroma, homogeneity, and pH values that were still within the safe range. All preparations showed pseudoplastic flow properties suitable for topical use. The antibacterial activity test showed that F1 and F2 produced inhibition zones of 10.72 ± 0.529 mm and 11.38 ± 0.764 mm, respectively, with a strong category, while F0 showed no antibacterial activity. Thus, the deodorant emulgel from dewandaru leaf extract has great potential to be developed as a natural-based antibacterial deodorant.

Keywords: Dewandaru; Deodorant; Emulgel; Leaf; *Staphylococcus aureus*.

INTRODUCTION

Body odor or bromhidrosis is a common problem that can affect self-confidence and social comfort. This condition occurs primarily in areas with high sweat production, such as the axillae, where sweat reacts with bacteria to produce volatile compounds with an unpleasant odor (Moghadam, 2025). One of the bacteria that can cause body odor include *Staphylococcus aureus*. *Staphylococcus* is capable of converting certain amino acids into short-chain volatile fatty acids with a strong odor, namely isovaleric acid, which plays a role in axillary odor (Handayani *et al*., 2022). This phenomenon drives many individuals to use personal care products such as deodorants to reduce the odor produced.

The use of deodorants containing chemicals at high concentrations can pose a risk of skin irritation in the axillary area. Therefore, one solution that can be applied is to develop deodorants based on natural ingredients to minimize these risks. In addition to being safer for the skin, the use of natural ingredients is also considered more economical compared to products based on synthetic chemical compounds (Nurfalah, 2024). One plant that has the potential to be used as a natural active ingredient is dewandaru (*Eugenia uniflora* L.).

Dewandaru is a tropical plant that contains various bioactive compounds. The leaves of dewandaru (*Eugenia uniflora L.*) were selected as the active ingredient in the formulation because they contain secondary metabolites such as flavonoids, tannins, phenolics, triterpenoids, and volatile compounds that play an important role in antibacterial, antioxidant, and anti-inflammatory activities (Falcão *et al*., 2018).

Previous studies have shown that the leaf extract of *E. uniflora* has been proven to possess antibacterial activity against *Staphylococcus epidermidis*, which is a microorganism that causes body odor (Rusmiati & Nursa'adah, 2017). Other research has shown that the leaf extract of dewandaru is able to inhibit the growth of *S. aureus* with a significant inhibition zone diameter at various concentrations (Lesmana & Pranitasari, 2023). In addition, dewandaru leaf infusion of dewandaru possessed antibacterial activity against *Staphylococcus*

aureus (Permadi, 2023), thereby strengthening the potential of Dewandaru leaves as a natural antibacterial agent. *Staphylococcus aureus* is a normal skin flora that acts as an opportunistic pathogen and plays a role in skin colonization and disorders in the axillary area, making this bacterium relevant for use as a test microorganism in topical deodorant preparations. Therefore, the leaf extract of *E. uniflora* can be formulated into a topical preparation.

Emulgel is a topical preparation in which the gel property supports the solubility of hydrophilic substances, while the emulsion property supports the delivery of hydrophobic substances. The advantages of emulgel include a lightweight texture like a gel as well as moisturizing capability like an emulsion. The selection of the emulgel preparation form is expected to produce a preparation with good consistency, easy application, and comfortable use, as well as being able to provide effectiveness in reducing body odor. Therefore, emulgel was chosen as a suitable topical preparation form for the formulation of deodorants with natural active ingredients because it is able to provide longer adhesion to the skin, good spreadability, and a comfortable sensation during use (Bakri *et al*., 2023).

Based on the antibacterial potential and benefits of the leaf extract of dewandaru (*Eugenia uniflora*), the research on the emulgel formulation of dewandaru extract is still limited. Therefore, this study aimed to formulate and test the antibacterial activity of an emulgel containing dewandaru leaf extract against *Staphylococcus aureus*. The results of this study is expected to produce a practically applicable herbal deodorant product with proven antibacterial activity against *S. aureus*.

MATERIALS AND METHODS

Materials

The materials used in this study were *Eugenia uniflora* (dewandaru) leaves (reference number 1021/UN2.F3.11/PDP.02.00/2025) obtained from Palsigunung (Depok, West Java, Indonesia), 70% ethanol, 90% ethanol, Carbopol 940, oleic acid, liquid paraffin, glycerin, Span 80, Tween 80, methyl paraben, propyl paraben, TEA (triethanolamine), tocopherol, fragrance, distilled water, NA, 0.9% NaCl, 10% DMSO (dimethyl sulfoxide), and MHA (Mueller–Hinton Agar).

Preparation of simplisia

The *Eugenia uniflora* leaves collected were fresh leaves aged approximately 2–4 months after sprouting, free of stains, tears, and insect damage. The harvested leaves were then gathered together. A total of 1.787 grams of the collected leaves were washed under running water, drained, and wiped dry to ensure that no dirt remained. The dewandaru leaves were subsequently dried using a drying cabinet (oven) at a temperature of 50°C to prevent damage to the active compounds. Dry sorting was then performed to separate foreign materials such as unwanted plant parts or impurities. The leaves were considered dry when they had turned brown, contained no moisture, and crumbled easily when crushed. The dried leaves were subsequently ground using a blender and then sieved through a 60-mesh sieve to produce a fine powder of dewandaru leaves. The resulting simplisia powder was then weighed to determine its final yield, producing 598.11 grams of dewandaru leaf simplisia powder (Anwar *et al*., 2022).

Ultrasonic Assisted Extraction

The extraction was performed using the UAE method with 70% ethanol as the solvent. A total of 400 grams of *dewandaru* leaf powder was placed into an Erlenmeyer flask, after which 70% ethanol was added at a solvent-to-simplisia ratio of 1:10. The mixture was then processed in an *Ultrasonic Powersonic 405* device at a temperature of 40°C for 45 minutes (Firdausia *et al*., 2025). Once the extraction was complete, the mixture was filtered using filter paper. The residue obtained from the first filtration was then re-added with 70% ethanol and re-extracted using UAE. Second filtration was carried out to obtain the second filtrate, which was subsequently evaporated using a rotary evaporator at a temperature of 50°C until a thick extract was obtained. Phytochemical screening of the leaf extract was carried out (Wenas et al. 2025).

Extract Antibacterial Activity

Antibacterial activity was evaluated using the disc diffusion method. The extract was tested at concentrations of 5% and 10%, with 1% chloramphenicol serving as the positive control and 10% DMSO as the negative control. A total of nine Petri dishes were prepared, allowing for three replicates. The sterilized Petri dishes were briefly warmed at the edges over a Bunsen flame to ensure aseptic conditions. *Staphylococcus aureus* bacteria were suspended in 0.9% physiological NaCl solution until the turbidity of the suspension matched the McFarland 3 standard. The bacterial suspension was then evenly streaked across the MHA medium in each Petri dish using a cotton swab (Zuzana et al., 2020). Sterile paper discs were placed onto the surface of the MHA using forceps, after which 20 µl of each test solution. 1% chloramphenicol (positive control), 10% DMSO (negative control), and dewandaru leaf extract at concentrations of 5% and 10%, was dripped onto the respective discs. The Petri dishes were incubated at 37°C for 24 hours. Antibacterial activity was assessed by measuring the diameter of the inhibition zone (clear zone) that formed around each disc using a caliper (Nilmawati et al., 2024).

Emulgel Formulation

The gel base was prepared by first dispensing Carbopol 940 into 100 mL of distilled water. The dispersion was

then left to swell for 30 minutes and stirred until homogeneous. Subsequently, TEA was added to the Carbopol dispersion, and the mixture was stirred again. Oleic acid was then incorporated and stirred until a stable gel base was formed. The oil phase was prepared by dissolving Span 80 in liquid paraffin, after which propyl paraben was added and the mixture was heated until reaching 70°C. Meanwhile, the water phase was prepared by mixing Tween 80, sorbitol, distilled water, and methyl paraben, which was then heated to the same temperature. Once both phases had reached 70°C, they were combined and homogenized until an emulsion was formed. The gel base was then mixed with the emulsion to produce the emulgel preparation. Subsequently, the dewandaru leaf extract was added and stirred until homogeneous. In the final step, tocopherol and fragrance were incorporated to the emulgel preparation (Bakri et al., 2023).

Table 1. Formulation of Dewandaru leaf extract.

Material	Formula (%)		
	F0	F1	F2
Leaf dewandaru extract	0	5	10
Carbopol	2	2	2
Asam oleat	1	1	1
Parafin	1.25	1.25	1.25
Gliserin	5	5	5
Span 80	2,5	2,5	2.5
Tween 80	17.5	17.5	17.5
Methyl paraben	0.18	0,18	0.18
Prophyl paraben	0.02	0.02	0.02
TEA	2	2	2
Tocopherol	0.05	0.05	0.05
Fragrance	qs	qs	qs
Aquadest	Ad 100	Ad 100	Ad 100

Evaluation of the Emulgel

Organoleptic Test

The physical appearance, color, and aroma of the dewandaru leaf extract emulgel preparation were observed during the organoleptic test (Bakri et al., 2023).

Homogeneity Test

A total of 100 mg of the sample was smeared onto a clear glass slide for the homogeneity test. The preparation was considered to meet the requirements if it exhibited a uniform texture and showed no visible coarse particles (Akib et al., 2023).

pH Test

The pH of the dewandaru leaf extract emulgel preparation was measured using a pH meter. The pH value of the preparation was considered acceptable if it fell within the skin pH range, namely between 4.5 and 6.5 (Akib et al., 2023).

Spreadability Test

The spreadability test was carried out by weighing 0.5 grams of the emulgel preparation and placing it in the center of a round glass plate with a marked scale and a diameter of 15 cm. The sample was covered with another glass plate and loaded with a 50-gram weight for one minute. Subsequently, additional weights of 100 grams and 150 grams were added successively. The test results were considered to meet the requirements if the spreadability fell within the range of 5–7 cm, indicating a semisolid consistency that would ensure comfortable use (Bakri et al., 2023).

Adhesion Test

A total of 0.5 g of the emulgel preparation was placed at the center of two glass objects and loaded with a 1 kg weight for 5 minutes. Thereafter, the two ends of the glass objects were hooked onto the testing apparatus. The adhesion was determined based on the length of time required for the two glass objects to separate (Erwiyani et al., 2022).

Viscosity and Flow Property Test

A total of 50 grams of the emulgel preparation was measured for viscosity using a Brookfield viscometer with spindle number 4 at a rotation speed of 60 rpm. The values for viscosity and flow properties were determined based on the readings indicated by the red pointer on the instrument scale (Erwiyani et al., 2022).

Stability Test of the Emulgel Preparation

In the cycling test method, the emulgel samples were stored at a temperature of 4°C for 24 hours, after which they were transferred to an oven at a temperature of 40°C for 24 hours (one cycle). The test was carried out for 6 cycles, and organoleptic observations, homogeneity, pH, spreadability, adhesion, viscosity, flow properties, and emulsion type were subsequently evaluated (Korengkeng et al., 2022).

Emulgel Antibacterial Activity

The antibacterial activity test was conducted using the well diffusion method. The emulgel was tested at concentrations of 0%, 5%, and 10%, with 1% chloramphenicol serving as the positive control and 10% DMSO serving as the negative control. A total of nine Petri dishes were prepared to allow for three replicates. The sterilized Petri dishes were briefly warmed at the edges over a Bunsen flame to ensure aseptic conditions. A volume of 1 mL of the *Staphylococcus aureus* bacterial suspension was poured into each Petri dish, after which MHA medium was added, homogenized, and left to solidify. Once the medium had hardened, wells were made using a perforator. The emulgel was then introduced into each well at a volume of 35 µL, with concentration variations of 0%, 5%, and 10%. The dishes were subsequently incubated at a temperature of 37 °C for 24 hours. The same procedure was carried out with 10% DMSO as the negative control and 1% chloramphenicol as the positive control. Antibacterial activity was observed through the formation of an

inhibition zone, indicated by a clear area surrounding the well, and the diameter of the zone was measured using a caliper (Agistia *et al*., 2023).

Data analysis

Data analysis in this study was performed to evaluate both the quality of the emulgel formulation and the effectiveness of its antibacterial activity against *Staphylococcus aureus*. The data obtained from the preparation evaluation (the organoleptic test, homogeneity test, pH measurement, spreadability test, adhesion test, flow property test, and viscosity test) were analyzed descriptively to assess their conformity with the characteristics expected of a topical preparation. The antibacterial activity data of the emulgel preparation were analyzed based on the diameter of the inhibition zones produced using the disc diffusion method and compared among the formulas. The results of the analysis were used to determine which emulgel formula exhibited the best physical quality as well as the most effective antibacterial activity in inhibiting the growth of *S. aureus*.

RESULTS AND DISCUSSION

Phytochemical Screening

The phytochemical screening conducted on the Dewandaru leaf powder and the 70% ethanol extract indicated that the secondary metabolites present in dewandaru (*Eugenia uniflora* L.) leaves are flavonoids, phenolics, and tannins, all three of which were detected positively in both the powder and the extract form. In contrast, the alkaloid, saponin, and triterpenoid groups were not detected during screening, indicating that the resulting metabolic profile is selective and dominated by polyphenolic compounds. This composition is consistent with the metabolic profile previously reported for *Eugenia uniflora* and supports the choice of 70% ethanol as the extraction solvent in this study, as this solvent specifically targets the extraction of flavonoids, phenolics, and tannins, compounds exhibiting polar to semi-polar characteristics (Candra et al., 2021).

Table 2. Phytochemistry screening of powder and extract of Dewandaru leaf.

Compound	Powder	Extract
Alkaloids	−	−
Flavonoids	+	+
Phenolics	+	+
Saponins	−	−
Tannins	+	+
Triterpenoids	−	−

The preparation of the dewandaru leaf simplicia was initiated using fresh leaves with an initial weight of 1,787 grams. After completing the entire drying process, the final weight of the simplicia obtained was 788 grams. The simplicia yield was 44%. Organoleptic examination of the powder revealed a green color, the characteristic aroma of dewandaru leaves, and a bitter taste.

Antibacterial activity of Dewandaru Leaf Extract

The antibacterial activity test results of the dewandaru (*Eugenia uniflora* L.) leaf extract against *Staphylococcus aureus* are presented in Table 3. Based on the measurement of the inhibition zone diameter, the Dewandaru leaf extract at concentrations of 5% and 10% exhibited antibacterial activity, as indicated by the formation of an inhibition zone around the disc. The mean inhibition zone diameter at 5% was 18.42 ± 0.950 mm, while at 10% it was 19.95 ± 1.566 mm. According to the standard classification of inhibition potency, both concentrations fall within the strong category, defined as a range of 10–20 mm. The increase in extract concentration from 5% to 10% demonstrated a tendency toward a larger inhibition zone diameter against *S. aureus*. This finding indicates that the antibacterial activity of the dewandaru leaf extract increases with concentration; specifically, the higher the extract concentration, the greater the bacterial growth-inhibiting capability. Although the increase in inhibition zone diameter was modest, the data nevertheless confirm a progressive improvement in antibacterial effectiveness with increasing extract concentration.

Table 3. Antibacterial of Dewandaru Leaf Extract.

Sample	Mean ± SD (mm)	Category
5% extract	18.42 ± 0.950	Strong
10% extract	19.95 ± 1.566	Strong
K^+	36.92 ± 0.326	Very Strong
K^-	0 ± 0	None

Notes: K^+ (1% chloramphenicol), K^- (10% DMSO)

The positive control (1% chloramphenicol antibiotic) produced a mean inhibition zone diameter of 36.92 ± 0.326 mm, which falls within the very strong category (>20 mm). This finding indicates that the antibiotic exhibits a substantially higher bacterial-growth-inhibiting capacity against *S. aureus* compared with the dewandaru leaf extract. This difference is expected, since antibiotics are pure compounds with a specific mechanism of action, whereas the dewandaru leaf extract remains a complex mixture of multiple active constituents and consequently exhibits lower antibacterial activity. In contrast, the negative control produced no inhibition zone, with a diameter of 0 mm, indicating that the solvent and the medium employed had no antibacterial activity against *S. aureus*. This confirms that the inhibition zones observed in the dewandaru leaf extract treatments were entirely attributable to the antibacterial activity of the bioactive constituents present in the extract, rather than to any solvent or medium effect.

Evaluation of dewandaru **Leaf Extract Emulgel**

Organoleptic observations

The organoleptic observations on emulgel formulations showed no change in form, color, or odor following accelerated stability testing (Table 4). With respect to the form parameter, all three formulas remained in a semi-solid state after the cycling test, indicating that no change in consistency or phase separation occurred as a result of temperature fluctuations during testing. This demonstrates that the base system and the composition of each formula were able to preserve their physical structure despite repeated exposure to alternating extreme temperatures.

Table 4. *Organoleptic observations.*

Formula	Parameter	Before Cycling Test	After Cycling Test
F0	Form	Semi-solid	Semi-solid
	Color	White	White
	Aroma	Characteristic odor	Characteristic odor
F1	Form	Semi-solid	Semi-solid
	Color	Brownish-green	Brownish-green
	Aroma	Characteristic odor	Characteristic odor
F2	Form	Semi-solid	Semi-solid
	Color	Brownish-green	Brownish-green
	Aroma	Characteristic odor	Characteristic odor

With respect to the color parameter, F0 remained white before and after the cycling test, whereas F1 and F2 retained their characteristic brownish-green color without any visible change. The absence of color change indicates that the formulation components, including the active ingredient and the excipients, possess good stability against temperature effects and did not undergo degradation or chemical reactions capable of altering the appearance of the preparation.

In addition, observation of the aroma parameter showed that all formulas retained their characteristic odor both before and after the cycling test. The absence of any odor change indicates that the preparations did not undergo chemical deterioration or microbial contamination during the testing process. Aroma stability further reflects that the active ingredient and excipients are relatively stable under the extreme storage conditions simulated through the cycling test. Overall, the stability test results obtained using the cycling test protocol demonstrate that formulas F0, F1, and F2 exhibit good physical stability, as evidenced by the absence of any change in the form, color, and aroma parameters after testing.

Homogeneity test

The homogeneity test is one of the parameters used in the physical-stability evaluation of semisolid preparations, as homogeneity reflects the uniform distribution of the active ingredient and the base within the formulation. A homogeneous preparation indicates the absence of phase separation or compositional non-uniformity, either of which can affect product quality, efficacy, and safety during storage. For this reason, homogeneity testing is commonly performed alongside physical-stability tests such as the cycling test, in order to evaluate the formulation's resilience against extreme temperature changes.

Table 5. Homogeneity test.

Formula	Before Cycling Test	After Cycling Test
F0	Homogen	Homogen
F1	Homogen	Homogen
F2	Homogen	Homogen

Based on the observations, all three formulas (F0, F1, and F2) exhibited a homogeneous state both before and after the cycling test. The absence of coarse granules, clumps, or textural variation in the preparations indicates that the base system employed was able to maintain a uniform distribution of components despite repeated exposure to temperature changes. This finding demonstrates that both the mixing process and the formulation composition produced a physically stable semisolid system. The retention of homogeneity after the cycling test indicates that temperature fluctuations did not induce phase separation within the preparations. This confirms that a preparation which remains homogeneous after cycling-test exposure can be classified as possessing good physical stability and is potentially stable under short-term storage conditions (Bakri *et al.*, 2023).

pH value

An appropriate pH value is essential to prevent skin irritation and damage. According to SNI No. 06-2588, the safe pH range for a topical preparation is 4.5–6.5. Preparations with excessively acidic pH can potentially cause irritation, while preparations with excessively basic pH can result in the skin becoming dry, rough, and flaky (Bakri et al., 2023).

Table 6. pH test of Dewandaru leaf extract emulgel.

Formula	Before Cycling Test	After Cycling Test
F0	4.87 ± 0.030	4.87 ± 0.005
F1	4.70 ± 0.023	4.65 ± 0.010
F2	4.65 ± 0.005	4.63 ± 0.005

The pH test results obtained before and after the cycling test showed that all formulas exhibited pH values that remained within the required range. F0 exhibited a pH value of 4.87 ± 0.03 before the cycling test and retained the same value of 4.87 ± 0.005 after the cycling test, indicating excellent pH stability. F1 showed a slight decrease in pH from 4.70 ± 0.023 to 4.65 ± 0.01; however, this change was relatively small and remained within the established limits. Similarly, in formula F2, the pH decreased only marginally from 4.65 ± 0.005 to 4.63 ± 0.005 after the cycling test. The pH changes observed in formulas F1 and F2 following the cycling test may be attributed to the effect of temperature fluctuations during storage, which can affect the emulgel system; however, these changes were not significant and did not compromise preparation safety.

These results are consistent with those reported in a previous study by Bakri et al., in which the pH values of topical preparations tended to decrease following stability testing. This decrease was attributed to temperature fluctuations during storage, which can affect the equilibrium of the emulgel system. Overall, it can be concluded that formulas F0, F1, and F2 exhibited stable pH values both before and after the cycling test, satisfied the topical-preparation pH requirements specified by SNI No. 06-2588, and are therefore safe for use on the skin.

Viscosity Evaluation

Viscosity testing was conducted to determine the viscosity level of an emulgel preparation. Viscosity represents the resistance of a substance to flow (Korengkeng et al., 2022). According to SNI 16-4399-1996, the acceptable viscosity range for a semisolid preparation is 6,000–50,000 cPs. Based on the viscosity test results obtained before and after the cycling test, all three formulas showed a decrease in viscosity values. This finding is consistent with Bakri et al. (2023), who reported a decrease in emulgel viscosity following a cycling test due to the influence of temperature on the gel structure. The post-cycling-test decrease in viscosity indicates that repeated storage at extreme temperatures can affect stability. This treatment has been shown to cause physical changes in the gel structure, including weakening of the polymer network and a reduction in the system's ability to retain its viscosity. A temperature-induced decrease in viscosity following repeated thermal treatment has also been reported in studies of gel and emulgel formulations based on hydrophilic polymers (Maslii et al., 2020).

Table 7. Viscosity Evaluation.

Formula	Before Cycling Test (cPs)	After Cycling Test (cPs)
F0	9.62 ± 1.834	6.59 ± 65.27
F1	9.62 ± 0.890	5.75 ± 50.79
F2	9.62 ± 2.560	4.31 ± 0.540

When comparing across formulas, F2 exhibited the lowest viscosity value after the cycling test, indicating that this formula was the most affected by accelerated storage conditions. In comparison, F0 and F1 showed a relatively smaller decrease in viscosity than F2, indicating that these two formulas retained viscosity more effectively throughout the cycling test. This stability can be attributed to a base composition that more effectively preserves the gel structure.

Based on the rheogram, all three formulas (F0, F1, and F2) demonstrated a decrease in viscosity with increasing rpm. This pattern indicates that all three preparations exhibit a non-Newtonian flow behavior of the pseudoplastic (shear-thinning) type. Pseudoplastic flow is characterized by a decrease in viscosity in response to increasing shear stress and is a typical feature of polymer-based gels and emulgels. This pseudoplastic behavior occurs because, under conditions of no or low shear stress, the polymer chains remain arranged in a compact three-dimensional network, producing a high viscosity. As shear stress increases, the polymer chains orient themselves in the direction of flow, weakening the interchain interactions and reducing flow resistance (Maslii et al., 2020).

This pseudoplastic flow behavior is the desired property in a topical preparation, as it allows the preparation to remain thick and stable during storage while becoming easier to spread once applied to the skin due to the reduction in viscosity that occurs when shear stress is applied. Accordingly, the flow properties of F0, F1, and F2 can be considered suitable for topical application.

The spreadability test

The spreadability test was conducted to determine the ability of the preparation to spread over the skin surface, which is directly related to the convenience of use, ease of application, and uniform distribution of the active ingredient. Good spreadability allows the preparation to be easily spread with light pressure, thereby increasing contact between the preparation and the skin. According to Bakri et al. (2023), a topical preparation exhibits acceptable spreadability within the range of 5–7 cm, as within this range the preparation is neither too thick nor too thin and therefore remains comfortable to use.

Table 8. Spreadability test.

Formula	Before Cycling Test (cm)	After Cycling Test (cm)
F0	5.17± 0.221	5.75 ± 0.057
F1	5.12 ± 0.250	4.82 ± 0.050
F2	5.32 ± 0.221	4.97 ± 0.050

Based on the test results, all formulas exhibited spreadability values that remained within the required range. F0 exhibited a spreadability of 5.17 ± 0.221 cm before the cycling test and increased to 5.75 ± 0.057 cm after the cycling test. This increase in spreadability indicates a slight decrease in the consistency of the preparation following temperature-cycled storage; however, the value remained within acceptable limits. F1 exhibited a spreadability of 5.12 ± 0.25 cm before the cycling test and decreased to 4.82 ± 0.05 cm after the cycling test, while formula F2 decreased from 5.32 ± 0.221 cm to 4.97 ± 0.05 cm. The decrease in spreadability observed in F1 and F2 indicates a decrease in viscosity following the cycling test; however, the values remained close to and did not deviate significantly from the established standard range.

The post-cycling-test changes in spreadability can be attributed to changes in the physical structure of the preparation caused by high and low temperature fluctuations during storage. Temperature fluctuations can influence particle interactions within the emulgel system, thereby affecting viscosity and directly impacting the spreadability of the preparation. In general, spreadability is inversely proportional to viscosity, such that preparations with lower viscosity tend to exhibit greater spreadability, and vice versa (Khan et al., 2022).

Adhesion test

The adhesion test was conducted to determine the ability of the topical preparation to adhere to the skin surface, as good adhesion affects the duration of contact between the preparation and the skin and thereby enhances the effectiveness of the active ingredient. A semisolid preparation with good adhesion generally exhibits values within the range of 4–7 seconds (Bakri et al., 2023). Based on the test results obtained before and after the cycling test, all formulas exhibited adhesion values that remained within the required range; accordingly, the preparations can be considered to possess good adhesion capability.

Table 9. Adhesion test.

Formula	Before Cycling Test (cm)	After Cycling Test (cm)
F0	8.00 ± 1.732	5.56 ± 0.513
F1	4.66 ± 0.435	4.89 ± 0.115
F2	4.14 ± 0.169	4.33 ± 0.305

In F0, the adhesion before the cycling test was 8 ± 1.732 seconds and decreased to 5.56 ± 0.513 seconds after the cycling test. This decrease in adhesion indicates the influence of temperature fluctuations during storage, which can cause changes in the physical structure of the preparation, particularly in the emulgel system and thereby reduce the adhesive strength to the surface. Nevertheless, the post-cycling-test adhesion value remained within the acceptable range, so the preparation continued to satisfy the requirements. Formulas F1 and F2 exhibited relatively small changes in adhesion following the cycling test. In F1, the adhesion increased from 4.66 ± 0.435 seconds to 4.89 ± 0.115 seconds, whereas in F2 the value increased from 4.14 ± 0.169 seconds to 4.33 ± 0.305 seconds. This increase indicates that the emulgel structure of both formulas was sufficiently stable against the influence of temperature fluctuations.

Antibacterial activity test of Dewandaru leaf extract emulgel

The antibacterial activity test results against *Staphylococcus aureus* revealed a clear difference between the formulas. F0 did not produce any inhibition zone, with a mean value of 0 ± 0 mm, and was therefore classified as exhibiting no antibacterial activity. This result indicates that the preparation base without the addition of the active ingredient was unable to inhibit the growth of the test bacteria. This finding further confirms that the excipients used in the base formulation possessed no antibacterial influence of their own (Frent et al., 2023).

Table 10. Antibacterial of Dewandaru Leaf Extract.

Sample	Mean ± SD (mm)	Category
F0	0 ± 0	None
F1	10.72 ± 0.529	Strong
F2	11.38 ± 0.764	Strong
K+	33.1 ± 1.315	Very Strong
K-	0 ± 0	None

Notes: K^+ (1% chloramphenicol), K^- (10% DMSO)

In contrast to F0, F1 and F2 produced inhibition zones with mean values of 10.72 ± 0.529 mm and 11.38 ± 0.764 mm, respectively. Based on the inhibition-power classification, both formulas fell into the strong category, defined as values within the range of 10–20 mm. The emergence of inhibition zones in F1 and F2 indicates that the incorporation of the active ingredient into the preparation contributed to the inhibition of *Staphylococcus aureus* growth. This organism is a Gram-positive bacterium with a thick peptidoglycan layer, which makes it relatively more sensitive to antibacterial compounds of natural origin, particularly phenolic and flavonoid compounds, which are known to compromise cell-wall and bacterial-membrane integrity (Yuan et al., 2021).

The positive control exhibited a very large inhibition power with a mean value of 33.1 ± 1.315 mm and was classified as very strong. This is consistent with the more

specific mechanism by which standard antibiotics inhibit bacterial protein or cell-wall synthesis. Conversely, the negative control exhibited no inhibition zone, confirming that the solvent or medium used possessed no antibacterial activity of its own. Accordingly, the inhibition produced by F1 and F2 can be attributed directly to the presence of the active ingredient in the preparation rather than to any other factor. Overall, these results demonstrate that F1 and F2 possess antibacterial activity against *Staphylococcus aureus*, although their effectiveness remains below that of standard antibiotics. Nonetheless, this strong level of activity indicates the potential of the preparation for development as a natural-source antibacterial alternative, particularly for topical use with the advantage of a lower risk of side effects and resistance compared with synthetic antibiotics.

The antibacterial activity of the ethanol extract of dewandaru leaves was evaluated using the disc diffusion method, in which 20 µL of test solution was loaded onto a 6 mm paper disc. This method is appropriate for fluid preparations such as ethanolic extracts, which can be evenly absorbed into paper discs and produce reproducible inhibition zones. In contrast, the finished emulgel preparation was evaluated using the well diffusion method, in which 35 µL of the semisolid formulation was loaded directly into wells cut into the agar medium. This method is appropriate for semisolid preparations such as emulgels, creams, and gels, whose viscosity prevents uniform absorption into paper discs and would therefore yield irreproducible zone diameters. Both protocols used the same bacterial strain (*Staphylococcus aureus*), the same McFarland standard inoculum (1.5×10^8 CFU/mL), the same MHA medium, the same incubation temperature (37 °C), and the same incubation duration (24 hours), and both protocols employed 10% DMSO as the negative control and 1% chloramphenicol as the positive control in every test plate. Each method has been previously validated for its respective sample format (Agistia et al., 2023), and the use of a methodologically appropriate protocol for each physical form of the test article is the approach recommended in standard pharmaceutical microbiology references.

CONCLUSIONS

The formulations F0, F1, and F2 are suitable for use in the manufacture of deodorant emulgel, as all formulas exhibited physical characteristics consistent with topical preparations and remained stable after performing the cycling test. The dewandaru -leaf-extract deodorant emulgel exhibited good quality and physical stability. All formulas satisfied the evaluation parameters for topical preparations, with pH values of 4.63–4.87, viscosity within the standard range of 6,000–50,000 cPs, spreadability of 4.82–5.75 cm, and adhesion of 4.33–5.56 seconds before and after the cycling test. All preparations remained homogeneous abd exhibited no organoleptic changes. The deodorant emulgel formulations containing 5% and 10% dewandaru leaf extract exhibited antibacterial activity against *Staphylococcus aureus*, with inhibition zone diameters of 10.72 ± 0.529 mm and 11.38 ± 0.764 mm, respectively, classifying them within the strong category. The extract-free preparation exhibited no antibacterial activity (0 ± 0 mm), whereas the positive control exhibited an inhibition zone of 33.1 ± 1.315 mm, classifying it within the very strong category. This confirms that the dewandaru leaf extract served as the antibacterial active ingredient within the formulation and has potential for further development as a natural-source topical deodorant.

Acknowledgements: The authors would like to acknowledge the LPPM of Institut Sains dan Teknologi Nasional, which has provided research funding through the Internal Grant 2026 of ISTN LPPM under Contract Number 048/05-B.09/IV/2026.

Authors' Contributions: Desy Muliana Wenas designed the study. Diny Aulia Mawarni carried out the laboratory work. Herdini analyzed the data. Desy Muliana Wenas & Diny Aulia Mawarni wrote the manuscript. All authors read and approved the final version of the manuscript.

Competing Interests: The authors declare that there are no competing interests.

Funding: The authors would like to thank the LPPM of Institut Sains dan Teknologi Nasional, which has provided research funding through the Internal Grant 2026 of ISTN LPPM under Contract Number 048/05-B.09/IV/2026.

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