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Original Article

Physicochemical Characterization and Dual-Antimicrobial Efficacy of *Ananas comosus* Peel Extract Nano-Shampoo Against Scalp Pathogens

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Abstract

Background: Pineapple peel (*Ananas comosus* (L.) Merr.) is an agricultural waste that contains various secondary metabolites with antimicrobial potential.
Objective: This study aimed to formulate a pineapple peel extract into a nano-shampoo preparation and evaluate its physical quality characteristics and antimicrobial activity against *Malassezia furfur* and *Staphylococcus epidermidis*.
Methods: The nano-shampoo was formulated with three different concentrations of extract: 3% (FI), 6% (FII), and 9% (FIII). Physical quality evaluation included organoleptic observations, homogeneity, pH, viscosity, foam height, and storage stability. Antimicrobial activity was tested in vitro using the agar diffusion method and analyzed.
Results: The results showed that all nano-shampoo formulations met the physical quality requirements and exhibited good stability. All formulations demonstrated antimicrobial activity against *M. furfur* and *S. epidermidis*, as indicated by the formation of inhibition zones. Statistical analysis showed that the positive control produced significantly larger inhibition zones than all nano-shampoo formulations ($p < 0.05$), whereas no significant differences were observed among formulations FI, FII, and FIII ($p > 0.05$). Nevertheless, the 9% extract formulation (FIII) descriptively exhibited the largest inhibition zones among the tested nano-shampoo formulations.
Conclusion: Based on these results, pineapple peel extract nano-shampoo has the potential for development as a natural-based preparation with antimicrobial activity, particularly as a supportive alternative for scalp care.

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INTRODUCTION

Dandruff is a common scalp disorder characterized by excessive shedding of the stratum corneum, often accompanied by itching and discomfort. Its pathogenesis is strongly associated with alterations in the scalp microbiome, particularly the proliferation of lipophilic *Malassezia* species, which metabolize sebum lipids into irritating metabolites that can disrupt the skin barrier and trigger inflammation. In addition, opportunistic commensal bacteria such as *Staphylococcus epidermidis* have been implicated in scalp dysbiosis and may contribute to local inflammatory processes. Emerging evidence suggests that interactions between *Malassezia* and *Staphylococcus* species influence microbial ecology and may exacerbate the severity of dandruff and related scalp disorders.[1,2]

Dandruff is typically treated using anti-dandruff shampoos that contain synthetic active ingredients such as zinc pyrithione and ketoconazole.[3] Although conventional antidandruff agents are generally effective, some may cause local adverse effects in susceptible individuals, and dandruff may recur after treatment discontinuation.[4,5] This situation has led to increased interest in the development of natural alternatives, which are expected to be safer and more suitable for long-term use.

Pineapple peel (*Ananas comosus* (L.) Merr.) is an agricultural waste produced in large quantities by the food industry, and its utilization has been limited. Various studies have reported that pineapple peel contains secondary metabolites such as flavonoids, alkaloids, saponins, and tannins, as well as the enzyme bromelain, which are known to have biological activities, including antimicrobial activity against bacteria and fungi.[6–9] Methanolic pineapple peel

extract exhibited antimicrobial activity against several bacterial and fungal strains, with the strongest inhibition observed against *Pseudomonas fluorescens*, *Staphylococcus aureus*, *Fusarium sp*., and *Tilletia indica*; its activity against *Bacillus megaterium* was also evaluated.[10] Ethanolic pineapple peel extract also exhibited in vitro antifungal activity against *Trichophyton mentagrophytes* and *Malassezia furfur.*[11] The use of pineapple peel as an active ingredient in pharmaceutical formulations not only has the potential to increase the value of this waste but also aligns with the principles of sustainability and the development of products based on local natural resources.[8,9]

The development of topical formulations based on natural ingredients faces a major challenge regarding the stability of active compounds and their effectiveness in reaching the target site.[12] Nanotechnology has been widely applied in topical formulations because it can improve the physical stability, homogeneity, and biological activity of active ingredients by increasing the surface area and achieving a more uniform particle distribution.[13,14] In shampoo formulations, nanotechnology is expected to enhance the interaction between active ingredients and microorganisms causing scalp disorders while supporting the effectiveness of the formulation without increasing the risk of irritation.[15]

Among the various nano-based delivery systems, nanoemulsions are particularly suitable for shampoo formulations because they are composed of biocompatible oil, water, and surfactants that can be easily incorporated into conventional cleansing products without substantially altering their rheological properties. Compared with liposomes and solid lipid nanoparticles, nanoemulsions are generally simpler to prepare, more cost-effective, and exhibit high physical stability while efficiently solubilizing hydrophobic phytochemicals. In addition, their small droplet size provides a larger surface area, which enhances contact between the active compounds and the scalp surface, thereby potentially improving antimicrobial efficacy and the retention of bioactive constituents during shampoo applications. These advantages make nanoemulsion systems particularly attractive for the development of natural anti-dandruff shampoo formulations.

Recent evidence from systematic reviews and comprehensive review articles has highlighted the increasing potential of natural products as alternative agents for dandruff management because of their combined antimicrobial, anti-inflammatory, antioxidant, and scalp-protective properties. Compared with conventional synthetic agents, plant-derived bioactive compounds are considered promising for long-term scalp care due to their lower risk of adverse effects and broader pharmacological activities. Furthermore, recent advances in nano-based topical drug delivery systems have demonstrated that nanoformulations can significantly improve the stability, solubility, skin penetration, controlled release, and bioavailability of phytochemicals, thereby enhancing their therapeutic efficacy. Collectively, these findings provide a strong scientific basis for developing nano-shampoo formulations containing medicinal plant extracts as innovative natural alternatives for managing scalp disorders.[3,16]

Recent studies have demonstrated that dandruff is associated not only with fungal overgrowth but also with alterations in the scalp bacterial microbiota. Besides *Malassezia* spp., *Staphylococcus epidermidis* is one of the dominant bacterial species inhabiting the healthy scalp. Under dysbiotic conditions, changes in its abundance and interaction with *Malassezia* may contribute to scalp inflammation, impairment of the skin barrier, and persistence of dandruff symptoms. Therefore, evaluating antimicrobial activity against both fungal and bacterial scalp-associated microorganisms may provide a broader assessment of the therapeutic potential of novel anti-dandruff formulations.

Although the antimicrobial potential of pineapple peel extract has been widely documented, studies investigating its formulation into nano-shampoo preparations and evaluating its activity against both *Malassezia furfur* and *Staphylococcus epidermidis* remain limited. Previous nano-shampoo research has focused only on pineapple core extract and assessed antidandruff activity against a single pathogen, *Malassezia furfur.*[15] To date, no study has examined pineapple peel extract in a nano-shampoo system with broader antimicrobial evaluation targeting both fungal and bacterial scalp pathogens.

Therefore, this study aimed to formulate pineapple peel extract into a nano-shampoo preparation and evaluate its physicochemical characteristics and antimicrobial activity against *Malassezia furfur* and *Staphylococcus epidermidis*. Comprehensive characterization of the pineapple peel extract was also performed to identify its major bioactive constituents and support formulation development. Beyond providing scientific evidence of antimicrobial efficacy, this study may contribute to the development of standardized natural-based nano-shampoo products utilizing agricultural waste as a value-added raw material. The findings may also provide preliminary evidence to support future product optimization, safety evaluation, and regulatory assessment prior to clinical application, thereby facilitating the translation of sustainable plant-based formulations into topical scalp care products.

METHODS

Tools. The primary tools that influenced the research results included an analytical balance (*Kenko*), rotary evaporator (*Buchi*), ultrasonic probe homogenizer (*Qsonica sonicator*), Viscometer (NDJ-5S), calibrated pH meter (*Hanna instruments edge*), Particle Size Analyzer (PSA), and UV-Vis spectrophotometer (Genesys 30, Thermo Fisher Scientific, USA). Additionally, supporting equipment such as an autoclave (GEA), incubator (*Memmert*), laminar air flow (*Biobase*), and standard laboratory glassware and microbiological supplies were used to support sample preparation, formulation, and testing.

Materials. The main material used in this study was pineapple peel (*Ananas comosus* (L.) Merr.) as the raw material for the extract and 96% ethanol as the solvent. The shampoo base ingredients included sodium lauryl sulfate (SLS), cocamidopropyl betaine, glycerin, sodium benzoate, essential oils, deionized water, and citric acid. Additionally, materials for forming and stabilizing the nanosystem were used. The test microorganisms were *Malassezia furfur* and *Staphylococcus epidermidis*. Sabouraud Dextrose Agar (SDA) was used for the growth of *M. furfur*, while Nutrient Agar (NA) was used for *S. epidermidis*. The positive control was 2% ketoconazole shampoo, and the negative control was deionized water.

Research Procedure

Plant Identification

The plant identification was carried out to confirm the botanical identity of the test material used in the study.[17] Pineapple peel samples were obtained from fresh pineapples and subsequently identified at the SITH ITB institution. The identification process was based on the morphological characteristics of the plant and was matched with relevant taxonomic literature.

Preparation and Characterization of Simplisia

The pineapple peel was washed with running water to remove dirt, then cut into small pieces and dried to reduce the moisture content, turning it into simplisia. The dried simplisia was characterized using the following tests:

Macroscopic Examination: Macroscopic examination was conducted by directly observing a small portion of the simplisia based on its physical condition. The characteristics observed included the shape, color, odor, and texture of the pineapple peel simplisia (*Ananas comosus* (L.) Merr.).[18]

Microscopic Examination: Microscopic examination was performed using a light microscope at 40× magnification to identify diagnostic characteristics including parenchyma cells, stone cells, and calcium oxalate crystals.[18]

Moisture Content Determination: The moisture content of the simplicia was determined using the gravimetric method as described in previous study.[19] All tests were performed in triplicate to ensure consistency of the results The moisture content of simplisia should not exceed 10%, as it could affect the quality of simplisia.[20]

Determination of Water-Soluble Extract and Ethanol-Soluble Extract Content: The determination of water-soluble and ethanol-soluble extract content was conducted according to the method described previously using water–chloroform (97.5:2.5) and 96% ethanol as solvents to evaluate the solubility of polar and semipolar compounds. The filtrates were evaporated to dryness and heated at 105°C to constant weight to calculate the extract content.[21]

Pineapple Peel Extraction

Pineapple peel simplisia was extracted using the maceration method with 96% ethanol for 3 × 24 h with periodic agitation. The filtrate obtained from maceration was filtered and evaporated using a rotary evaporator until a thick extract was obtained. The resulting thick extract was weighed, and the yield was calculated before being stored in a sealed container for further use in the next stage.[17]

$$\%Yield = \frac{weight\ of\ extract\ (grams)}{Weight\ of simplisia\ (grams)} \text{x}\ 100\%$$

Phytochemical Screening of Extract

Qualitative phytochemical screening of the pineapple peel extract was performed using specific reagent-based tests to identify major classes of secondary metabolites. The presence of each metabolite class was determined based on characteristic color changes or precipitate formation.[22] In this study, phytochemical screening was conducted to identify the presence of flavonoids, alkaloids, saponins, tannins, terpenoids, and steroids, according to previously reported methods.[23]

Pineapple Peel Extract Nanoemulsion Preparation

The pineapple peel extract nanoemulsion was prepared using probe ultrasonication following a high-energy emulsification approach. Tween 80 and PEG 400 were mixed until the mixture was clear and homogeneous, after which virgin coconut oil (VCO) was added to the mixture of Tween 80 and PEG 400. Next, the mixture was incorporated into the pre-dissolved extract and stirred using a magnetic stirrer for 20 min at 800 rpm and 80°C. The mixture was then homogenized using an ultrasonic probe homogenizer for 30 min to obtain a homogeneous and stable nanoemulsion. The detailed formula composition is presented in **Table 1**.

The nanoemulsion composition consisting of virgin coconut oil (VCO), Tween 80, and PEG 400 was selected based on previous reports demonstrating its suitability for topical nanoemulsion formulations. VCO served as the oil phase to dissolve lipophilic phytochemical constituents, while Tween 80, a nonionic surfactant with a high hydrophilic–lipophilic balance (HLB), facilitated the formation of a stable oil-in-water nanoemulsion. PEG 400 was used as a co-surfactant to further reduce the interfacial tension, improve droplet dispersion, and enhance the physical stability of the nanoemulsion during ultrasonication.

Table 1. Formulation of Pineapple Peel Extract Nanoemlsion

Ingredients	Quantity
Pineapple peel extract	2 g
VCO	0.6 g
Tween 80	7.2 g
PEG 400	4 g
Deionized water	20 mL

Characterization of Particle Size and Polydispersity Index (PDI) of Nanoemulsion

The particle size and Polydispersity Index (PDI) of the pineapple peel extract nanoemulsion system were characterized before formulation into the shampoo base. Particle size and PDI were measured according to previously reported methods, a PDI value below 0.3 indicates a homogeneous particle size distribution.[24] Particle Size Analyzer (PSA) testing was performed to ensure the formation of a nanosized dispersion system and to evaluate the particle distribution homogeneity. This characterization was performed on the pure nanoemulsion and was not repeated after the nanoemulsion was formulated into the shampoo formulations (FI, FII, and FIII).

Formulation of Nanoemulsion Shampoo

The nano-shampoo formulations were prepared using three different extract concentrations: 3% (FI), 6% (FII), and 9% (FIII), as shown in **Table 2**. All formulations were homogenized until a homogeneous and stable nanosized shampoo was achieved. The pH was adjusted using citric acid to match that of the human scalp.

Table 2. Pineapple Peel Extract Nano Shampoo Formulation

Ingredients	Concentration (%w/v)			Function
	FI	FII	FIII	
Pineapple peel extract nanoemulsion	3	6	9	Active ingredient
SLS (Sodium Lauryl Sulfate)	10	10	10	Surfactant
Cocamidopropyl betaine	5	5	5	Co-surfactant
Glycerin	2	2	2	Humectant
Sodium Benzoate	0.2	0.2	0.2	Preservative
Essential oil	0.5	0.5	0.5	Fragrance
Deionized water	q.s. to 100	q.s. to 100	q.s. to 100	Solvent
Citric acid	Sufficient amount	Sufficient amount	Sufficient amount	pH stabilizer

Physical Evaluation of Nano Shampoo

Organoleptic Stability Test. The organoleptic stability test was performed by observing the stability of the physical parameters of the formulation, such as color, odor, shape, and homogeneity, at specific time intervals to assess the stability of the formulation during storage process.[25]

pH Measurement. The pH of the shampoo formulation was measured using a universal pH indicator to determine its acidity level and ensure skin compatibility.[26]

Viscosity Test. The viscosity of the shampoo preparations was measured using an NDJ-5S digital rotational viscometer equipped with spindle No. 2 at a rotational speed of 60 rpm. The shampoo sample was placed in a 100-mL beaker, and the spindle was immersed until the marked line on the spindle was aligned with the surface of the sample. After an equilibration period of approximately 30 s, the viscosity value displayed by the instrument was recorded in mPa·s. Measurements were performed at room temperature without specific temperature control. The measurement procedure was conducted according to the operating principles of the NDJ-5S viscometer.[27]

% Transmittance Test. The percent transmittance test was performed to evaluate the clarity of the dispersed nano system, following procedures described in previous studies.[28,29] A transmittance value of ≥90% indicates adequate clarity and suitability for further nano-system characterization.[28,29]

Particle Size and Distribution Analysis (Particle Size Analyzer). Particle size analysis was conducted using a Particle Size Analyzer based on laser light scattering principles, following previously reported methods.[30] Nanoemulsions are generally characterized by an average particle size within the range of 1–500 nm.

Foam Height Test. Foam height was evaluated to assess the cleansing performance of the nano-shampoo formulation, following previously reported procedures.[31] Briefly, 1 g of the sample was dispersed in 10 mL of distilled water, shaken to generate foam, and the foam height was recorded after 5 minutes.

Antimicrobial Activity Test

The antimicrobial activity of the pineapple peel extract nano-shampoo was evaluated in vitro using the agar disk diffusion method on Nutrient Agar (NA) for *Staphylococcus epidermidis* and modified Sabouraud Dextrose Agar (SDA) supplemented with lipid for *Malassezia furfur*, following previously reported procedures.[32–36] Before inoculation, microbial suspensions were standardized using the 0.5 McFarland standard (approximately 1.5×10^8 CFU/mL) to ensure uniform microbial density during antimicrobial testing. Sterile paper discs impregnated with the positive control (2% ketoconazole shampoo, diluted), negative control, and nano-shampoo formulations (FI, FII, and FIII) were placed on inoculated agar surfaces, incubated under appropriate conditions, and the inhibition zone diameters were measured using a caliper and recorded in millimeters. Each sterile paper disc (6 mm diameter) was impregnated with 20 µL of the respective test sample before being placed on the inoculated agar surface. The antimicrobial assay was performed in triplicate (n = 3), and the inhibition zone diameters were expressed as mean ± standard deviation. For *Malassezia furfur*, inoculated plates were incubated at 32°C/35°C for 48–72 h on lipid-supplemented Sabouraud Dextrose Agar under aerobic conditions.

Data Analysis

The test data were analyzed statistically using SPSS software at a 95% confidence level. Normality and homogeneity tests were performed as prerequisites for the analyses. Data that met the parametric assumptions were analyzed using one-way ANOVA followed by a Tukey test to determine differences between treatment groups. Those that did not meet the assumptions were analyzed using the nonparametric Kruskal-Wallis test. Statistical significance was set at $p < 0.05$.

RESULT AND DISCUSSION

Plant Identification

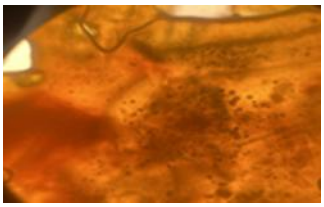
The plant identification results showed that the sample used in this study was identified as pineapple (*Ananas comosus* (L.) Merr.) and belongs to the Bromeliaceae family with identification number 1913/IT1.C11.2/TA.00/2025. This identification confirmed that the raw material used matched the reported plant species and was suitable for use as the subject of the research.

Preparation and Characterization of Pineapple Peel Simplicia

Macroscopic Examination. The macroscopic examination of the pineapple peel simplicia was conducted by directly observing the physical condition of the pineapple peel simplicia used. The macroscopic observation showed that the pineapple peel simplicia used had an elongated shape, measuring approximately ±2–3 cm in length and ±1–2 cm in width, with a rough surface. The simplicia appeared yellowish-brown, reflecting the natural characteristics of the pineapple peel after drying. Sensory evaluation indicated that the simplicia had a sweet taste and characteristic pineapple aroma, suggesting that the volatile components and natural compounds were well preserved.

Microscopic observation. The Microscopic observation revealed several diagnostic characteristics of pineapple peel simplicia, including parenchyma cells, stone cells, and calcium oxalate crystals (**Table 3**). These findings confirmed the authenticity of the plant material.[15,18]

Table 3. Microscopic Observation Results of Simplicia

Name of Object	Sample	Reference
Parenchyma		
Stone cell		
Calcium Oxalate		

Moisture Content Test. The moisture content test is an essential part of ensuring the quality of the simplicia during storage. The moisture content was 2.2%, which complies with the Indonesian Materia Medica (MMI) requirement of not more than 10%.

Results of Water-Soluble Extract and Ethanol-Soluble Extract Tests. Water-soluble and ethanol-soluble extract tests are preliminary identification steps before conducting phytochemical screening to identify the types of active compounds that are polar, semi-polar, or nonpolar present in the simplicia. The water-soluble and ethanol-soluble extract contents were 42.1% and 7.29%, respectively, which meet the requirements of the MMI, with values of ≥37% and ≥3%, respectively[14]. This result indicates that the simplicia contains compounds soluble in both polar and semi-polar solvents.

Extraction Yield of Pineapple Peel

Pineapple peel was extracted using the maceration method with 96% ethanol, resulting in a thick, dark brown extract with a characteristic pineapple odor. The yield calculation was 29.05%, This yield is comparable with previous studies indicating that the extraction successfully drew soluble compounds from the simplicia.[37] The obtained yield value demonstrates that pineapple peels have good potential as a source of bioactive compounds.

Phytochemical Screening of Pineapple Peel Extract

Phytochemical screening is a preliminary identification process used to study the chemical compounds in pineapple peel extracts. The phytochemical screening of pineapple peel extract revealed the presence of several groups of secondary metabolites, including flavonoids, alkaloids, saponins, tannins, terpenoids, and steroids, which is consistent with the findings of previous studies [15,38]. The presence of these compounds suggests the potential of pineapple peel extract, particularly as an antimicrobial agent. These phytochemical screening results are consistent with the antimicrobial activity observed against *Malassezia furfur* and *Staphylococcus epidermidis*, where phenolic

compounds and flavonoids are known to inhibit microorganism growth by disrupting cell membranes and enzymatic systems.[28]

Characterization of Pineapple Peel Extract Nanoemulsion

The nanoemulsion of pineapple peel extract was characterized prior to incorporation into the shampoo base to confirm the successful formation of a nano-sized dispersion system. Particle Size Analyzer (PSA) results showed an average hydrodynamic diameter of 369.4 ± 0.0314 nm, indicating relatively consistent particle size. This value falls within the nanoemulsion range (<500 nm), suggesting effective homogenization through the combination of surfactants and ultrasonication. The polydispersity index (PDI) of 0.2707 ± 0.0130, which is below 0.3, indicates a relatively homogeneous and physically stable particle size distribution. Furthermore, the transmittance value (89.8 ± 0.45%) reflects high system clarity, while the diffusion coefficient of 1.10 ± 0.10 $\mu m^2/s$ indicates stable particle movement, confirming the formation of a well-dispersed submicron system.

This characterization was performed at the nanoemulsion stage before being formulated into the shampoo base. Thus, the obtained particle size represents the delivery system of the active ingredient, which is consistently used across all shampoo formula variations (FI–FIII), where the differences between formulas lie only in the volume of nanoemulsion added to the shampoo base matrix.

Physical Characteristics of Nano Shampoo

The results of the organoleptic stability evaluation of the pineapple peel extract nano shampoo during storage on days 0, 7, and 14 showed that all formulations (FI–FIII) maintained their characteristics of shape, color, odor, and homogeneity with a score of 5 (very stable). No significant physical changes were observed during the observation period, indicating that the nanoemulsion system effectively maintained the physical and organoleptic stability of the formulation. The physical appearance of the three formulations is shown in **Figure 1**.



Figure 1. Nano-shampoo formulations containing pineapple (*Ananas comosus* (L.) Merr.) peel extract at concentrations of 3% (FI), 6% (FII), and 9% (FIII), arranged from left to right.

The pH test showed a decrease in pH values with increasing concentrations of pineapple peel extract. Formula FI (3%) had the highest pH value at 6.50 ± 0.32, while formula FIII (9%) showed the lowest pH at 4.77 ± 0.04. Statistical analysis showed a significant difference in pH values between formulations ($p < 0.001$), especially between FI and FII/FIII, while the difference between FII and FIII was not significant. The decrease in pH is suspected to be related to the higher content of organic acids in the extract at higher concentrations.[39] However, all formulations remained within the pH range that is safe for the scalp.[40] One-way ANOVA demonstrated a significant difference in pH among the formulations ($p < 0.05$). Tukey's HSD analysis further confirmed that increasing pineapple peel extract concentration significantly decreased the pH of the nano-shampoo formulations.

The decrease in pH with increasing pineapple peel extract concentration is likely associated with the presence of naturally occurring organic acids and phenolic compounds in the extract. From a pharmaceutical perspective, maintaining the pH within the physiological scalp range is crucial because slightly acidic formulations help preserve the integrity of the scalp barrier, maintain the acid mantle, and support the balance of the resident scalp microbiota. Consequently, although increasing extract concentration significantly reduced the pH, all formulations remained within the acceptable range for topical application, indicating their suitability for scalp use.[41,42]

Similar trends have been reported in herbal shampoo formulations containing plant extracts, where increasing extract concentration resulted in a gradual decrease in pH because of the higher content of organic acids and phenolic compounds. Nevertheless, maintaining the formulation within the physiological scalp pH range is essential to preserve the acid mantle and minimize irritation.

The viscosity test showed that formula FIII (9%) had a higher viscosity compared to FI (3%) and FII (6%). The Kruskal-Wallis test showed a significant difference between formulations (p = 0.043), and the Mann-Whitney post-test indicated that FIII was significantly different from FI and FII, while FI and FII showed no significant difference. The increased viscosity in FIII is suspected to be due to the higher dissolved solid content of the extract, which affects the intermolecular interactions in the formulation matrix.[43] Although there were significant statistical differences, all the physical parameters remained within an acceptable range for topical shampoo formulations, ensuring user comfort.[44,45] Statistical analysis revealed significant differences in viscosity among the formulations (one-way ANOVA, $p < 0.05$). Pairwise comparisons using Tukey's HSD indicated that formulations containing higher extract concentrations exhibited significantly greater viscosity than those containing lower concentrations.

The increase in viscosity observed with higher extract concentrations may be attributed to the greater amount of dissolved phytochemicals and enhanced intermolecular interactions within the formulation. In topical formulations, viscosity is an important quality attribute because it influences product spreadability, residence time on the scalp, and the release profile of active compounds. A moderately increased viscosity may prolong contact between the formulation and the scalp, potentially enhancing antimicrobial efficacy while maintaining acceptable consumer usability.[46,47]

Similar increases in viscosity following higher concentrations of plant extracts have also been reported in previous topical formulations. This phenomenon is attributed to the increased total dissolved solids and stronger intermolecular interactions within the formulation matrix. This observation is consistent with previous reports on herbal shampoo formulations, where increasing extract concentration increased viscosity due to the higher amount of dissolved solids and stronger intermolecular interactions within the formulation matrix. Appropriate viscosity is important because it influences shampoo spreadability, user acceptability, and retention time on the scalp.

The transmittance values of the nano shampoo showed a decreasing trend with increasing extract concentrations. Formula FI had the highest transmittance value at 99.83 ± 0.05%, while FIII had the lowest at 96.73 ± 0.05%. Statistical analysis showed a significant difference between all formulations ($p < 0.05$). The decrease in transmittance indicates reduced clarity due to the higher concentration of active ingredients, but all formulations still met the characteristics of a nano-based system.[48-49] One-way ANOVA showed that transmittance differed significantly among the formulations ($p < 0.05$), with Tukey's HSD indicating a significant reduction in transmittance as the concentration of pineapple peel extract increased.

The gradual reduction in transmittance with increasing extract concentration reflects the incorporation of a greater amount of dispersed phytochemicals within the nanoemulsion rather than indicating formulation instability. Despite the decrease in optical clarity, all formulations exhibited transmittance values above 90%, suggesting that the dispersed droplets remained sufficiently small and uniformly distributed. High transmittance is generally associated with nanoscale droplet formation and effective stabilization of the dispersed phase, indicating that the surfactant system successfully prevented significant particle aggregation.[50,46]

Particle size characterization using the Particle Size Analyzer (PSA) showed an average particle diameter of 0.3694±0.0314 µm with a polydispersity index (PDI) of 0.2707±0.0130, indicating a relatively homogeneous and stable particle size distribution. The consistency of particle size and transmittance values supports the stability of the nanoemulsion system formed, since both parameters are commonly used as indicators of nanoemulsion stability and homogeneity.[51] Particle size characterization was performed at the nanoemulsion stage before formulation into the shampoo base to ensure that the active ingredient delivery system was optimally formed. This approach aimed to validate the success of nano system formation before applying concentration variations in the final formulation.

Since the formula variations (FI, FII, and FIII) only involved differences in the amount of nanoemulsion added to the shampoo base without altering the composition of the nanoemulsion system itself, the particle size is assumed to remain consistent across formulations. Therefore, the observed differences in antimicrobial activity and physical characteristics are more related to variations in the concentration of active ingredients in the formulation matrix, rather than changes in the particle size of the nano system.

The small particle size obtained in this study is advantageous for topical drug delivery because nanosized droplets provide a larger interfacial surface area, facilitating closer interaction between the active compounds and the scalp surface. In addition, the relatively low polydispersity index indicates a homogeneous particle size distribution, which contributes to formulation stability by minimizing droplet aggregation during storage. Previous studies have demonstrated that nano-sized delivery systems improve the penetration, retention, and bioavailability of phytochemicals in topical formulations, thereby potentially enhancing therapeutic efficacy.[52]

The particle size was characterized only once at the nanoemulsion stage prior to incorporation into the shampoo base. Therefore, no statistical comparison among formulations FI, FII, and FIII was performed because all formulations were prepared using the same nanoemulsion system.

The average particle size of approximately 369 nm obtained in this study is comparable to nanoemulsion systems reported in previous topical delivery studies, which generally range between 100–500 nm. Such particle size is considered appropriate for improving formulation stability and facilitating closer interaction between active compounds and the scalp surface. Therefore, the present findings support the theoretical advantages of nano-based topical delivery systems reported in previous pharmaceutical studies.

The foam height evaluation showed differences in foam stability among the formulations. Formula FI showed a smaller foam height difference compared to FII and FIII, indicating relatively better foam stability. Meanwhile, formula FIII showed a greater decrease in foam height, which is suspected to be influenced by increased viscosity and the dissolved solid content of the extract. However, all formulations still produced adequate foam suitable for a shampoo product.[53] Foam stability also differed significantly among formulations (one-way ANOVA, $p < 0.05$), with Tukey's HSD indicating that higher extract concentrations produced slightly lower foam stability, although all formulations remained within the acceptable specification.

Foam formation is an important quality parameter affecting consumer perception and product acceptance, although it is not directly correlated with cleansing efficacy. The slight decrease in foam stability at higher extract concentrations may result from interactions between phytochemical constituents and surfactant molecules, which can alter foam film elasticity. Nevertheless, the observed foam stability remained within acceptable limits, indicating that the incorporation of pineapple peel extract did not adversely affect the functional performance of the shampoo formulation.[39,54]

The high foam stability observed in all formulations indicates that the incorporation of pineapple peel extract did not adversely affect the foaming performance of the shampoo. This finding is important because foam stability is closely associated with consumer acceptance, although it is not directly related to cleansing efficacy.

Antimicrobial Activity

The results of the inhibition zone diameter measurements for each formula are presented as shown in **Figure 2** and **Table 4**. All nano shampoo formulations were able to inhibit the growth of both microbes, as indicated by the formation of inhibition zones around the test disks. Overall, the statistical analysis (**Table 4**) showed that the variation in pineapple peel extract concentration in formulations FI, FII, and FIII did not result in significant differences in antimicrobial inhibition against both *Malassezia furfur* and *Staphylococcus epidermidis* ($p > 0.05$). This could be influenced by the relatively small increase in extract variation within the formulation and relatively similar composition of secondary metabolites among the formulations. The phenomenon is called the plateau effect, where increasing the concentration does not necessarily result in a significant increase in activity.[55,56]

Table 4. Inhibition Zone Diameter of Pineapple Peel Extract Nano Shampoo

Group	Inhibition Zone Diameter (mm) Mean ± SD	
	Malassezia furfur	***Staphylococcus epidermidis***
Negative Control (K-)	0.00 ± 0^{c}	0.00 ± 0^{c}
Positive Control (K+)	12.86 ± 0.63^{a}	10.31 ± 0.10^{a}
FI (3%)	9.68 ± 0.62^{b}	8.28 ± 0.90^{b}
FII (6%)	9.81 ± 0.53^{b}	7.91 ± 0.51^{b}
FIII (9%)	10.15 ± 1.02^{b}	8.46 ± 0.59^{b}

Different letters indicate a significant difference ($p < 0.05$).

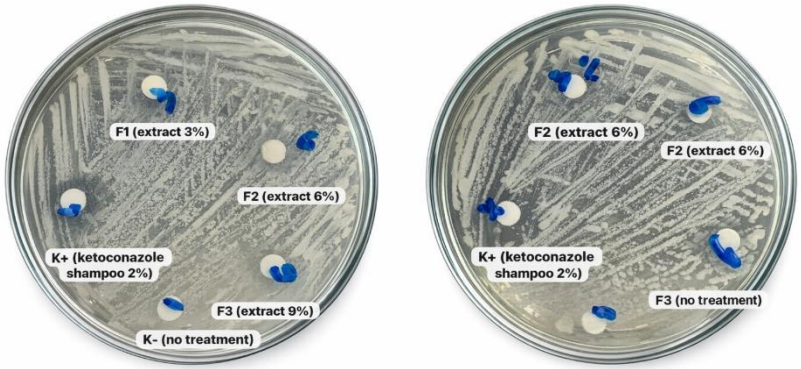


Figure 2. Microbial Assay on Petri Dishes. Left: *Malassezia furfur*; Right: *Staphylococcus epidermidis*.

However, all formulations exhibited significant antimicrobial activity compared to the positive control ($p < 0.05$), confirming the potential of the pineapple peel extract nano shampoo as a natural-based formulation with antimicrobial activity, One-way ANOVA showed significant differences among formulations ($p < 0.05$), followed by Tukey's HSD test. This activity may be attributed to the presence of bioactive phytochemicals in pineapple peel, including phenolic compounds and flavonoids, which have previously been reported to possess antimicrobial properties.[57] The 9% formulation showed the highest inhibition zone among the nano-shampoo formulations, indicating a concentration-dependent antimicrobial effect.

In general, the inhibition zone diameter against *Malassezia furfur* was larger than that against *Staphylococcus epidermidis* for all formula variations. The comparison of microorganism sensitivity is shown more clearly in **Figure 3**. This suggests that the pineapple peel extract nanoemulsion system has relatively more dominant antifungal activity compared to antibacterial activity. This difference in sensitivity is suspected to be related to the structural differences in the cell walls and membrane composition between fungi and Gram-positive bacteria. Based on the research conducted, the antimicrobial activity of pineapple peel extract was found to be more significant against the fungus *Malassezia furfur*.

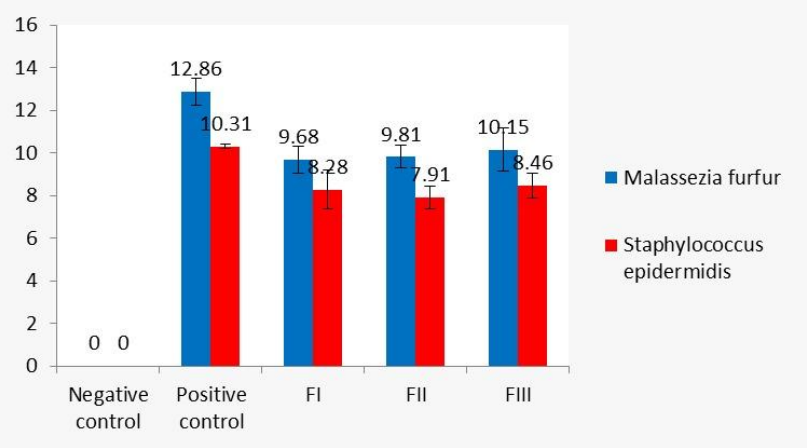


Figure 3. Comparison of inhibition zone diameters (mm) of pineapple peel extract nano shampoo against *Malassezia furfur* and *Staphylococcus epidermidis*.
FI, FII, and FIII contained 3%, 6%, and 9% pineapple peel extract, respectively. Data are presented as mean ± SD (n = 3).

The antimicrobial activity test results of the pineapple peel extract nano shampoo against *Malassezia furfur* and *Staphylococcus epidermidis* demonstrate the potential of bioactive compounds in pineapple peel, such as flavonoids and bromelain.[58] Both compounds were reported inhibit lipophilic fungi.[59] These findings are consistent with previous studies demonstrating that pineapple peel contains bioactive secondary metabolites, including alkaloids and terpenoids, which may contribute to its observed antibacterial activity.[60,61] Phenolic compounds and flavonoids have been reported to exhibit antimicrobial activity through multiple mechanisms, including disruption of cell wall integrity, alteration of cytoplasmic membrane permeability, interference with intracellular metabolic processes, and inhibition of microbial protein and nucleic acid synthesis, ultimately suppressing the growth of pathogenic bacteria and fungi.[62,63]

The lack of significant statistical differences among the formulations suggests that increasing the extract concentration within the tested range did not result in a meaningful increase in antimicrobial activity. This phenomenon indicates that the relationship between extract concentration and inhibition activity is not linear, especially in natural-based formulations. These findings are in line with several studies reporting that the antimicrobial effectiveness of herbal extracts can reach a saturation point (plateau), meaning that further increases in concentration do not always lead to a significant rise in inhibition activity.[64-65]

Statistical analysis demonstrated significant differences in antimicrobial activity among the treatment groups (one-way ANOVA, $p < 0.05$). Tukey's HSD test further showed that all pineapple peel extract nano shampoo formulations exhibited significantly lower inhibition zones than the positive control, although increasing extract concentrations from 3% to 9% resulted in progressively greater antimicrobial activity. The 9% formulation produced the highest inhibition among the tested formulations, indicating a concentration-dependent effect. These findings suggest that higher concentrations of pineapple peel extract provide greater amounts of bioactive compounds, such as flavonoids, tannins, phenolics, and bromelain, which contribute to microbial growth inhibition. Although the

antimicrobial activity of the nano shampoo was significantly lower than that of the positive control, its marked inhibitory effect relative to the negative control suggests its potential as a natural-based adjunctive topical formulation. Previous studies have demonstrated that optimization of nanoemulsion delivery systems can enhance the antimicrobial performance of natural bioactive compounds by improving their stability, bioavailability, and interaction with microbial cells.[30,66]

This study has several limitations. First, the antimicrobial evaluation was conducted exclusively under in vitro conditions using the agar diffusion method, which may not fully represent in vivo scalp conditions, including sebum composition, skin barrier interactions, and microbiome complexity. Second, the investigation focused on two representative scalp pathogens, which, although relevant, may not encompass the full diversity of microorganisms associated with scalp disorders. Third, the study did not include long-term stability or clinical efficacy assessments; therefore, further in vivo and extended stability studies are recommended to strengthen the translational application of the formulation. The antimicrobial activity observed in this study is in agreement with previous reports demonstrating that pineapple peel extract possesses inhibitory activity against dandruff-associated microorganisms because of its flavonoid, tannin, saponin, and bromelain contents. The antimicrobial activity is likely attributed to the synergistic action of flavonoids, tannins, saponins, and bromelain. Flavonoids may disrupt microbial cell membranes, tannins precipitate cellular proteins, while bromelain has been reported to interfere with microbial adhesion and biofilm formation.

The antimicrobial activity observed in the present study is generally consistent with previous reports demonstrating the inhibitory effect of pineapple peel extract against *Malassezia furfur* and several Gram-positive bacteria. Octaviani et al.[11] reported that ethanol extract of pineapple peel exhibited antifungal activity against *M. furfur*, whereas Soni et al.[10] and Mursidah et al.[6] demonstrated antibacterial effects against *Staphylococcus aureus*. The present study extends these findings by demonstrating that pineapple peel extract retains its antimicrobial activity after incorporation into a nano-shampoo formulation against both *M. furfur* and *Staphylococcus epidermidis*. This suggests that nanoformulation does not diminish the biological activity of the extract while simultaneously providing acceptable physicochemical characteristics suitable for topical application. From a theoretical perspective, antimicrobial activity is likely associated with the synergistic action of flavonoids, tannins, saponins, and bromelain. Flavonoids disrupt microbial cell membranes, tannins precipitate cellular proteins, whereas bromelain may interfere with microbial adhesion and biofilm formation. The nanoemulsion system may further enhance the interaction between these bioactive compounds and microbial cells through increased surface area and improved dispersion.

The positive control produced significantly larger inhibition zones than all nano-shampoo formulations. This finding is expected because ketoconazole is a synthetic antifungal agent with a well-established mechanism of inhibiting ergosterol biosynthesis, whereas pineapple peel extract contains naturally occurring antimicrobial compounds with comparatively lower specific activity.

Limitations

The antimicrobial activity of the nano-shampoo was lower than that of the positive control, and increasing the extract concentration did not produce statistically significant differences among the formulations ($p > 0.05$). The study was also limited to laboratory-based physicochemical and antimicrobial evaluations. Long-term stability, scalp irritation, in vivo safety, and clinical effectiveness were not assessed. Further studies should therefore evaluate these parameters and refine the formulation to improve its antimicrobial performance.

CONCLUSION

This study successfully formulated Ananas comosus peel extract into a nano-shampoo with acceptable physicochemical properties. The nanoemulsion had a mean particle size of 369.4 ± 0.0314 nm and a PDI of 0.2707 ± 0.0130, indicating a relatively homogeneous submicron system. The formulations maintained acceptable pH, viscosity, foam stability, and organoleptic characteristics during the evaluated storage period. All formulations exhibited antimicrobial activity against *Malassezia furfur* and *Staphylococcus epidermidis*, with the 9% extract formulation producing the largest inhibition zones. These findings demonstrate the potential of A. comosus peel extract nano-shampoo as a natural-based supportive formulation for controlling dandruff-associated microorganisms while promoting the valorization of pineapple peel waste.

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GENERATIVE AI DISCLOSURE STATEMENT

The authors declare that no generative artificial intelligence (AI) or AI-assisted technologies were used in the preparation of this manuscript.

AUTHOR CONTRIBUTION STATEMENT

Iwan Saka Nugraha: conceptualization, research execution, data analysis, and manuscript writing; **I Gede Made Agus Artawiguna**: supervision and manuscript review; **Ida Bagus Putra Mahardika**: data analysis and final manuscript review; **I Gusti Agung Ayu Kartika**: Writing- Reviewing and Editing.

CONFLICT OF INTEREST DECLARATION

The authors declare that there is no conflict of interest.

REFERENCE

1. Deng L, Ling X, Li L, He Y, Guo M. Advances in Scalp Microbiome Research: Molecular Insights into the Metabolism-Inflammation-Barrier Axis and Dandruff Pathogenesis. Molecules. 2026; 31(12):2093. doi: 10.3390/molecules31122093
2. Han Y, Zhang YJ, Wang HX, Sun YZ, Yang Y, Li ZX, Qi RQ, Gao XH. Malassezia furfur promoting growth of Staphylococcus epidermidis by increasing pH when cultured in a lipid-free environment. Chin Med J (Engl). 2019;132(7):873-876. doi: 10.1097/CM9.0000000000000152
3. Yin CS, Minh Nguyen TT, Yi EJ, Zheng S, Oh S, Yi T. Efficacy of probiotics in hair growth and dandruff control: A systematic review and meta-analysis. *Heliyon*. 2024;10(9):e29539. doi: 10.1016/j.heliyon.2024.e29539
4. Tynes BE, Johnson CD, Vaish MH, Abbott B, Vučenovic J, Varrassi G, Potharaju P, Lopez Torres Y, Lee Z, Ahmadzadeh S, Shekoohi S, Kaye AD. Ketoconazole Shampoo for Seborrheic Dermatitis of the Scalp: A Narrative Review. *Cureus*. 2024;16(8):1-8. doi: 10.7759/cureus.67532
5. Mayser P, Genrich F, Meunier L, Nordzieke S. Scalp Microbiome and Dandruff—Exploring Novel Biobased Esters. *Cosmetics*. 2024;11(5):174. doi: 10.3390/cosmetics11050174
6. Mursidah A, Salam S, Agustina R. Profil Fitokimia dan Uji Aktivitas Antibakteri Ekstrak Kulit Buah Nanas (Ananas comosus (L.) Merr) [Phytochemical Profile and Antibacterial Activity Testing of Pineapple Peel Extract (Ananas comosus (L.) Merr.)]. *Proceeding Mulawarman Pharm Conf*. 2023;18:1-6. doi: 10.25026/mpc.v18i1.695
7. Aliyah SH, Musfirotun, Antriana N. Aktivitas Antibakteri Isolat Kapang Endofit Dari Kulit Nanas (Ananas comosus (L .) Meer). *BIOSENSE*. 2021;04(2):20-30. doi: 10.36526/biosense.v4i02.1569
8. Mgeni ST, Emmanuel JK, Mtashobya LA. Potential Contributions of Pineapple Waste to Nutrition, Medicine, Bioenergy Sources, and Environmental Conservation: A Review. *Nat Prod Commun*. 2025;20(6). doi: 10.1177/1934578X251348402
9. Paz-Arteaga SL, Cadena-Chamorro E, Goméz-García R, Serna-Cock L, Aguilar CN, Torres-León C. Unraveling the Valorization Potential of Pineapple Waste to Obtain Value-Added Products towards a Sustainable Circular Bioeconomy. *Sustainability*. 2024;16(16):7236. doi: 10.3390/su16167236
10. Soni S, Noor U, Sharma A, Tripathi SM, Sundaram S, Gupta E. Assessment of antimicrobial potential of polyphenol-rich Ananas comosus peel powder at different drying conditions. *Indian J Nat Prod Resour [Formerly Nat Prod Radiance (NPR)]*. 2025;16(3):417-427. doi: 10.56042/ijnpr.v16i3.15228
11. Octaviani M, Fikrani D, Susanti E. Aktivitas Antijamur Ekstrak Etanol Kulit Buah Ananas comosus (L) Merr. terhadap Trichophyton mentagrophytes dan Malassezia furfur [Antifungal Activity of Ethanolic Pineapple Peel Extract (Ananas comosus (L.) Merr.) against Trichophyton mentagrophytes and Malassezia furfur]. *JFIOnline | Print ISSN 1412-1107 | e-ISSN 2355-696X*. 2020;12(2):159-165. doi: 10.35617/jfionline.v12i2.35
12. Jacob S, Nair AB. Nanoemulgels as Advanced Topical Drug Delivery Systems: Mechanistic Insights and Therapeutic Applications in Skin Disorders, Infections, Wound Healing, and Cancer. *Pharmaceuticals*. 2026;19(2):247. doi: 10.3390/ph19020247

13. Jannah RNS, Illiyyin Akib N, Ode Sitti Zubaydah W, Mahmudah A, Septiani Pratiwi I, Anwar I. Review: Pengaruh Polimer Sebagai Stabilizer Terhadap Ukuran Partikel Nanosuspensi (Review: The Effect of Polymer as Stabilizers on Particle Size of Nanosuspensions). *Lansau J Ilmu Kefarmasian*. 2025;3(1):19-26. doi: 10.33772/lansau.v3i1.40
14. Preeti, Sambhakar S, Malik R, et al. Nanoemulsion: An Emerging Novel Technology for Improving the Bioavailability of Drugs. Bolla PK, ed. *Scientifica (Cairo)*. 2023;2023:1-25. doi: 10.1155/2023/6640103
15. Lubis N, Lubis MS, Yuniarti R, Rani Z. Formulasi dan Evaluasi Sediaan Shampo Nano Ekstrak Bonggol Nanas (ananas comosus (l.) Merr) sebagai Antiketombe [Formulation and Evaluation of Nano Shampoo Preparation from Pineapple Stem Extract (ananas comosus (l .) Merr) as anti-dandruff]. *Mns DAN Kesehat*. 2025;8:285-297. doi: 10.31850/makes.v8i1.3509
16. Yan Z, Zhang S, Wu G, et al. Advances in Nanotechnology-Based Topical Delivery Systems for Skincare Applications. *Pharmaceutics*. Published online 2026:1-18. doi: 10.3390/pharmaceutics18010063
17. Syamsul ES, Anugerah O, Supriningrum R. Penetapan Rendemen Ekstrak Daun Jambu Mawar berdasarkan Variasi Konsentrasi Etanol Dengan Metode Maserasi [Determination Of Mawar Jambu Leaf Extract (Syzygium L. Alston)]. *J Ris KEFARMASIAN Indones*. 2020;2(3). doi: 10.33759/jrki.v2i3.98
18. Farobbi MI, Pratama IS, Hidayat LH. Studi Farmakognostik Serbuk Jus Kulit Nanas (Ananas comosus (L.) Merr) [Pharmacognostic Study of Pineapple (Ananas comosus (L.) Merr) Peel Juice Powder]. *Acta Pharm Indones*. 2025;50(1):47-55. doi: 10.5614/api.v50i1.24955
19. Martines-López E, Cárdenas-García D, Cywiak-Córdova D. Measuring Model for the Gravimetric Method by Drying in N-Stages Applied to Materials with High Moisture Content. *MAPAN*. 2024;39(2):439-443. doi: 10.1007/s12647-023-00709-y
20. Kissinger, Huldani H, Nasrulloh A V. Improving Simplicia of Kerangas Forest by Minimizing Microbial Content Under Ultraviolet Radiation Treatment. *Proc Natl Acad Sci India Sect B Biol Sci*. 2024;94(1):101-106. doi: 10.1007/s40011-023-01512-0
21. Raharjo SJ, Sari DRT, Maryanty Y, Tresnowati I, Wijayanti ED. Chemical Composition of Active Compounds in Standardized Cinnamon Simplicia (Cinnamomum verum). *Maj Obat Tradis*. 2025;30(3):315. doi: 10.22146/mot.100943
22. Castro ACL, Lubido ACC, Balderas AKA, Gonzales RKP, Saldo IJP. Phytochemical Analysis and Antibacterial Assessment of Pineapple (Ananas comosus) Peel Extract. *South Asian Res J Nat Prod*. 2025;8(1):153-161. doi: 10.9734/sarjnp/2025/v8i1188
23. Sari M, Imani CN, Wardani AP. Profil fitokimia eco enzyme berbahan dasar kulit nanas (Ananas comosus) dan daya antibakteri terhadap Lactobacillus acidophilus ATCC 4356: Studi eksperimental [Phytochemical profile of pineapple peel based eco enzyme and antibacterial activity against Lactobacillus Acidophilus ATCC 4356: Study experimental]. *Padjadjaran J Dent Res Students*. 2026;10(1):118-126. doi: 10.24198/pjdrs.v10i1.69215
24. Tinh NQ, Thanh D Van, Thu N Van, Thi B, Nhung Q, Huyen PN, Hung NP, Thuy NT, Thuy PD, Mi NH, Tam KT. Preparation of nanoemulsions from Elsholtzia kachinensis and Elsholtzia ciliata essential oils via ultrasonic homogenization and their antibacterial and anticancer activities. *R Soc Chem*. 2025;15:11243-11256. doi: 10.1039/d5ra00386e
25. Sbhatu DB, Berhe GG, Hndeya AG, Abdu A, Mulugeta A, Abraha HB, Weldemichael MY, Tekle HT, Gebru HA, Taye MG, Kidanemariam HG. Hair Washing Formulations from Aloe elegans Todaro Gel: The Potential for Making Hair Shampoo. *Adv Pharmacol Pharm Sci*. 2020;2020:1-9. doi: 10.1155/2020/8835120
26. Cheni Cheri D, Kizhakke Veettil AS, Pradeep P, Nayak S. Development of EPS-rich herbal shampoo base fermented using Cyclea peltata leaf powder and Lactobacillus plantarum. *J Cosmet Dermatol*. 2022;21(10):4999-5009. doi: 10.1111/jocd.14949
27. NDJ-5S / NDJ-8S SERIES DIGITAL DISPLAY VISCOMETER.
28. Mursyida E, Anjeli YP. Nanopartikel Perak dari Ekstrak Kulit Nanas: Potensi Antifungal terhadap Malassezia furfur ATCC 14521 [Silver Nanoparticles Synthesized from Pineapple Peel Extract: Antifungal Potential Against Malassezia furfur ATCC 14521]. *J Ilm Ilmu Kesehat dan Kedokt*. 2025;3:101-114. doi: 10.55606/termometer.v3i1.4563
29. Abdassah M. Nanopartikel dengan Gelasi Ionik [Nanoparticles Prepared by Ionic Gelation]. *Farmaka*. 2021;15:45-52. https://jurnal.unpad.ac.id/farmaka/article/view/12138
30. Anwar H, Aminah I, Syamsuriyati. Optimasi dan Uji Aktivitas Nanoemulgel Ekstrak Suruhan (Peperoma pellucida.L) Pada Bakteri MRSA [Optimization and Evaluation of the Antibacterial Activity of Suruhan (Peperomia pellucida L.) Extract Nanoemulgel Against MRSA]. *Pharmacol Pharm Sci Journals*. 2024;3(2):93-102. doi: 10.51577/papsjournals.v3i2.681
31. Zulbayu LOMA, Juliansyah R, Firawati. Optimasi Konsentrasi Sukrosa Terhadap Transparansi Dan Sifat Fisik Sabun Padat Transparan Minyak Atsiri Sereh Wangi (Cymbopogon citratus L.) [Optimization of Sucrose Concentration on the Transparency and Physical Properties of Transparent Solid Soap Containing Lemongrass Essential Oil (Cymbopogon citratus L.)]. *J Mandala Pharmacon Indones*. 2020;6(2). doi: 10.35311/jmpi.v6i1.60

32. Noverita Khairani T, Fitri K, Andry M, Eli Sarumaha Pl. Anti-Fungal Activity Testing of Purple Cabbage (Brassica oleracea Linn.) Ethanol Extract in Inhibiting The Fungi Growth Candida albicans and Malassezia furfur. *J Biol Trop*. 2024;24(4):991-1003. doi: 10.29303/jbt.v24i4.8009
33. Yanthi V, Mahyarudin M, Rialita A. Antifungal Activity of Endophytic Bacteria isolated from Pegagan (Centella asiatica L.) for Inhibition the Growth of Malassezia furfur. *J Biol UNAND*. 2022;10(1):23. doi: 10.25077/jbioua.10.1.23-32.2022
34. Apriliani PD, Kurniati I, Dermawan A, Indra AIN. Penggunaan Tepung Kacang Kedelai Hitam (Glycine soja L. Merr) Sebagai Media Alternatif Nutrient Agar (NA) Untuk Pertumbuhan Staphylococcus aureus [The Use of Black Soybean (Glycine soja) Flour as an Alternative Nutrient Agar (NA) Medium for the Growth of Staphylococcus aureus]. *J Kesehat Siliwangi*. 2023;4(1):268-276. doi: 10.34011/jks.v4i1.1490
35. Aviany HB, Pujiyanto S. Analisis Efektivitas Probiotik di dalam Produk Kecantikan sebagai Antibakteri terhadap Bakteri Staphylococcus epidermidis [Evaluation of the Antibacterial Efficacy of Probiotics in Cosmetic Products Against Staphylococcus epidermidis]. *Berk Bioteknol*. 2020;3(2). https://ejournal2.undip.ac.id/index.php/bb/article/view/9657
36. Rhimi W, Inyang Aneke C, Mosca A, Otranto D, Cafarchia C. In Vitro Azole and Amphotericin B Susceptibilities of Malassezia furfur from Bloodstream Infections Using E-Test and CLSI Broth Microdilution Methods. Antibiotics. 2020; 9(6):361. doi: 10.3390/antibiotics9060361
37. Neli A, Fitriyani F. Formulasi , Uji Sifat Fisik , Uji Stabilitas , dan Uji Aktivitas Antioksidan Gel Ekstrak Kulit Nanas (Ananas Comosus (L) Merr.) [Formulation, Physical Property Evaluation, Stability Testing, and Antioxidant Activity Assessment of Pineapple Peel (Ananas comosus (L.) Merr.) Extract Gel]. *LUMBUNG Farm*. 2025;6(1):1-6. doi: 10.31764/lf.v6i1.21142
38. Baitariza A, Ahmad Ghazali R. Formulasi Larutan Obat Kumur Pencegah Plak Gigi Ekstrak Kulit Nanas (Ananas comosus L. Merr) [Formulation of an Anti-Dental Plaque Mouthwash Containing Pineapple Peel (Ananas comosus (L.) Merr.) Extract]. *J Sabdariffarma*. 2020;6(1):33-42. doi: 10.53675/jsfar.v2i1.29
39. Sulhatun S, Juliati E, Sylvia N, Jalaluddin J, Bahri S. Formulasi Pembuatan Shampo dengan Bahan Baku Minyak Kemiri (Aleurites Moluccana) untuk Kesehatan Rambut [Formulation of a Shampoo Containing Candlenut (Aleurites moluccanus) Oil for Hair Health]. *J Teknol Kim Unimal*. 2022;11(1):32-42. doi: 10.29103/jtku.v11i1.7247
40. Mariska RP, Agung MH, Ibriyanti S. Formulasi dan Evaluasi Sifat Fisik Sediaan Shampo dari Ekstrak Daun Sungkai (Peronema canescens Jack) [Formulation and Evaluation of the Physical Properties of a Shampoo Containing Sungkai (Peronema canescens Jack) Leaf Extract]. *J Akad Baiturrahim Jambi*. 2025;14(September):403-414. doi: 10.36565/jab.v14i2.959
41. Kumar J, Azmal M, Faruk O, Shah ANM, Been N, Meem M, Ghosh A. Unlocking the secrets of the hair microbiome : From scalp health to therapeutic advances. *The Microbe*. 2025;7(April):100353. doi: 10.1016/j.microb.2025.100353
42. Deng L, Ling X, Li L, He Y, Guo M. Advances in Scalp Microbiome Research : Molecular Insights into the Metabolism-Inflammation-Barrier Axis and Dandruff Pathogenesis. *Molecules*. 2026;31(2093):1-29. doi: 10.3390/molecules31122093
43. Kartika DA, Legowo AM, Nurwantoro N. Pengaruh Penambahan Kurma terhadap Kadar Air, Derajat Keasaman (pH), Total Padatan Terlarut, dan Viskositas pada Yogurt Sari Kacang Hijau [Effect of Date Fruit Addition on Moisture Content, Acidity (pH), Total Soluble Solids, and Viscosity of Mung Bean Milk Yogurt]. *J Teknol Pangan*. 2025;9(2):64-69. doi: 10.14710/jtp.2025.51501
44. C. J. Thompson, N. Ainger, P. Starck, O. O. Mykhaylyk, A. J. Ryan, Shampoo Science: A Review of the Physiochemical Processes behind the Function of a Shampoo. Macromol. Chem. Phys. 2023, 224, 2200420. doi: 10.1002/macp.202200420
45. Thomas NA, Tungadi R, Ramadani D, Papeo P, Manoppo YS. Pengaruh Variasi Konsentrasi Ekstrak Buah Mahkota Dewa (Phaleria macrocarpa) terhadap Stabilitas Fisik Sediaan Krim [The Effect of Varying Concentrations of Mahkota Dewa (Phaleria macrocarpa) Fruit Extract on the Physical Stability of a Cream Formulation]. *Indones J Pharm Educ*. 2022;2(2):143-152. doi: 10.37311/ijpe.v2i2.13532
46. Zhang Z, McClements DJ. Chapter 2 - Overview of Nanoemulsion Properties: Stability, Rheology, and Appearance. In: Jafari SM, McClements DJBTN, eds. *Nanoemulsions*. Academic Press; 2018:21-49. doi: 10.1016/B978-0-12-811838-2.00002-3
47. Akbari S, Nour AH. Emulsion types, stability mechanisms and rheology : A review. *Int J Innov Res Sci Stud*. 2018;1(September):14-21. doi: 10.53894/ijirss.v1i1.4
48. Lestari L, Nita P, Tegar M. Formulasi dan Karakterisasi Nanopartikel Kitosan Ekstrak Daun Dadap Serep (Erythrina subumbrans) sebagai Kandidat Herbal Antimastitis [The Formulation and Characterization of Chitosan Nanoparticles from Dadap Serep (Erythrina Subumbrans) Leaf Extract as Antimastitic Herbal Candidate]. *J Kesehat Madani Med*. 2024;15(01):94-105. doi: 10.36569/jmm.v15i01.357
49. Tungadi R, Thomas NA, Gobel WG Van. Formulasi, Karakterisasi, dan Evaluasi Drops Liquid Self Nano-

Emulsifying Drug Delivery System (SNEDDS) Astaxanthin [Formulation, Characterization, and Evaluation of Liquid Self-Nano-Emulsifying Drug Delivery System (SNEDDS) Drops Containing Astaxanthin]. *Indones J Pharm Educ*. 2021;1(3):168-178. doi: 10.37311/ijpe.v1i3.11400

50. Wilson RJ, Li Y, Yang G, Zhao C xia. Nanoemulsions for drug delivery. *Particuology*. 2022;64:85-97. doi: 10.1016/j.partic.2021.05.009
51. Zhang Z, McClements DJ. Overview of nanoemulsion properties: stability, rheology, and appearance. In: Jafari SM, McClements DJ, eds. *Nanoemulsions*. Academic Press; 2018:21-49. doi: 10.1016/B978-0-12-811838-2.00002-3
52. Sandhya M, Ramasamy D, Sudhakar K, Kadirgama K, Harun WSW. Ultrasonication an intensifying tool for preparation of stable nanofluids and study the time influence on distinct properties of graphene nanofluids – A systematic overview. *Ultrason Sonochem*. 2021;73:105479. doi: 10.1016/j.ultsonch.2021.105479
53. Yuhara NA, Immanuel UK. Formulasi dan Uji Aktivitas Anti Ketombe P. Ovale Shampo Ekstrak Etanol Daun Murbei (Morus alba L.) [Formulation and Evaluation of the Anti-Dandruff Activity of Shampoo Containing Ethanolic Extract of Mulberry Leaves (Morus alba L.) Against Pityrosporum ovale]. *J Mhs Ilmu Farm dan Kesehat*. 2024;2(1):116-125. doi: 10.59841/jumkes.v2i1.877
54. Draelos ZD. Front Matter. In: *Cosmetic Dermatology*. ; 2022:i-xiv. doi: 10.1002/9781119676881.fmatter
55. Kurniaji A, Idris M, Muliani. Uji Daya Hambat Ekstrak Daun Mangrove (Sonneratia alba) pada Bakteri Vibrio harveyi secara In Vitro [In Vitro Evaluation of the Antibacterial Activity of Mangrove (Sonneratia alba) Leaf Extract Against Vibrio harveyi]. *J Sains Teknol Akuakultur*. 2021;3:84-92. https://core.ac.uk/outputs/267827180/
56. Rahayu KM, Chairani A. Efektivitas Anti Bakteri Ekstrak Daun Jengkol (Pithecellobiumjiringa) Terhadap Pertumbuhan Salmonellatyphimurium : Studi In Vitro Menggunakan Metode Difusi Cakram [In Vitro Evaluation of the Antibacterial Activity of Pithecellobium jiringa Leaf Extract Against Salmonella Typhimurium Using the Disk Diffusion Method]. *Biocaster J Kaji Biol*. 2025;5(3):287-297. doi: 10.36312/biocaster.v5i3.477
57. Soni S, Noor U, Sharma A, Tripathi SM, Sundaram S, Gupta E. Assessment of antimicrobial potential of polyphenol-rich Ananas comosus peel powder at different drying conditions. Indian Journal of Natural Products and Resources, 2025;16(3):417-427. doi: 10.56042/ijnpr.v16i3.15228
58. Nugraha IS, Udayani N, Aditama IGAS. Pengaruh Pemberian Elektrolit Buah Nanas terhadap Denyut Nadi Siswa SMK saat Melakukan Olahraga [Effect of Pineapple Fruit Electrolyte Supplementation on Heart Rate in Vocational High School Students During Physical Exercise]. *J Edukasi Citra Olahraga*. 2025;5:1-9. doi: 10.38048/jor.v4i3.4796
59. Mursidah A, Salam S, Agustina R. Profil Fitokimia dan Uji Aktivitas Antibakteri Ekstrak Kulit Buah Nanas (Ananas comosus (L.) Merr) [Phytochemical Profiling and Antibacterial Activity Evaluation of Pineapple (Ananas comosus (L.) Merr.) Peel Extract]. *Proceeding Mulawarman Pharm Conf*. 2023;18:1-6. doi: 10.25026/mpc.v18i1.695
60. Rahmawati I, Maulida R, Aisyah S. Potensi Antibakteri Sediaan Sabun Cair Ekstrak Kulit Nanas (Ananas comosus L. Merr.) Terhadap Bakteri Staphylococcus aureus ATCC 25923 [Antibacterial Potential of Liquid Soap Preparation Pineapple Peel Extract (Ananas comosus L. Merr.) Against Staphylococcus aureus ATCC 25923]. *J Farm Sains Indones*. 2021;4:1-11. doi: 10.52216/jfsi.vol4no2p1-11
61. Castro, A. C. L.; Lubido, A. C. C.; Balderas, A. K. A.; Gonzales, R. K. P.; Saldo, I. J. P. Phytochemical Analysis and Antibacterial Assessment of Pineapple (Ananas Comosus) Peel Extract. *S. Asian Res. J. Nat. Prod*. 2025;8:1: 153-161. doi: 10.9734/sarjnp/2025/v8i1188
62. De Rossi, L., Rocchetti, G., Lucini, L., & Rebecchi, A. Antimicrobial Potential of Polyphenols: Mechanisms of Action and Microbial Responses—A Narrative Review. Antioxidants, 2025:14(2), 200. doi: 10.3390/antiox14020200.
63. Nurnaningsih H, Laela DS. Efektivitas daya antibakteri berbagai konsentrasi enzim bromelain dari ekstrak buah nanas Ananas comosus (L .) Merr . terhadap Streptococcus mutans secara in-vitro [The antibacterial activity effectiveness of various concentrations of bromelain enzymes from pineapple (Ananas comosus (L.) Merr.) extract on Streptococcus mutans in-vitro]. *Padjadjaran J Dent Res Students*. Published online 2022. doi: 10.24198/pjdrs.v6i1.38211
64. Pradita D, Pertiwi I, Limbong YS. Tinjauan Literatur: Mekanisme Antibakteri Ekstrak Kulit Jeruk Purut (Citrus hystrix DC.) [Antibacterial Mechanisms of Kaffir Lime (Citrus hystrix DC.) Peel Extract: A Literature Review]. *J Indah Sains dan Klin*. 2025;06(01):26-39. doi: https://doi.org/10.52622/jisk.v6i1.04
65. Rosida A, Hujjatusnaini N, Adah A. Flavonoid Profile of Peperomia pellucida Extract and Its Potential for Ophthalmic Therapy. *J Syifa Sci Clin Res*. 2025;7(3):412-422. doi: 10.37311/jsscr.v7i3.34643
66. Celine RG, Muhammad HM, Sujit B, Vincent HT, Kendra PR, Wei L, Xinli L; Nanoemulsion delivery systems for enhanced efficacy of antimicrobials and essential oils. *Biomater. Sci*. 2022;10(3):633–653. doi: 10.1039/d1bm01537k