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Formulation and Evaluation of Nano ECO-PINAS (Eco-friendly Pineapple Shampoo) Pineapple peel extract *(Ananas comosus* (L.) *Merr)* as an anti-dandruff agent

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Abstract

Nano ECO-PINAS *(Eco-friendly Pineapple Shampoo)* is a Nano shampoo made from pineapple peel waste. Dandruff is a scalp problem. One cause of dandruff is the fungus *Malassezia furfur. Malassezia furfur* is a cause of dandruff. This study aims to evaluate the nano-preparation of pineapple peel shampoo *(Ananas comosus)* using physical tests in accordance with SNI standards and to assess its ability to inhibit the growth of Malassezia furfur. The study used the True Experimental method, in which pineapple peel is extracted, made into nanoparticles, and then formulated into various shampoo preparations. Evaluation includes particle size analysis (PSA), physical testing, and antifungal activity testing. The study showed that pineapple peel nanoextracts can be formulated into anti-dandruff shampoos that meet SNI physical test standards. All formulations have good physical quality, with a pH of 5.0–9.0, a viscosity of 400–4000 cps, stable foam, and a moisture content below 95%. The cleaning power ranges from 32–66%, with higher values indicating greater shampoo effectiveness in removing dirt and oil. Antifungal activity tests against *Malassezia furfur* showed that F3 had the largest inhibition zone (22.6 mm), followed by F2 (19.75 mm) and F1 (19.5 mm). For comparison, the blank inhibition zone was 1.86 mm, the ketoconazole positive control was 22.9 mm, and the comparative sample was 19.6 mm. The results of the One-Way ANOVA test ($\alpha = 0.05$) showed a p-value of $p = 0.00$, indicating a significant difference between the pineapple peel nanoextract shampoos at concentrations of 3%, 6%, and 9% and the commercial shampoo. This data shows that the nanoextract of pineapple peel *(Ananas comosus)* formulated into the shampoo can inhibit the growth of *Malassezia furfur.*

Keywords: eco-pinas, Malassezia furfur, nano, pineapple peel, shampoo

Introduction

In this context, converting agricultural waste into value-added products is an important strategy to support sustainability and resource efficiency. Processing agricultural waste is one concrete example. Effective management of organic waste is crucial, as organic matter left to accumulate without proper handling can become a breeding ground for pests and pose health risks.[1]

Pineapple *(Ananas comosus)* is one of the tropical fruits widely consumed around the world, including in Indonesia. It is popular for its sweet, refreshing flavor and rich

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nutritional content, including vitamin C, fiber, antioxidants, and the enzyme bromelain.[2] Pineapple consumption is not limited to fresh fruit; pineapples are also processed into a variety of products such as juice, electrolyte beverages, jam, candied fruit, and other processed foods. High levels of pineapple consumption also generate large amounts of organic waste, especially pineapple peels.[3]

Nano ECO-PINAS (Eco-friendly Pineapple Shampoo) is a nano shampoo made from pineapple peels. Producing natural shampoo from pineapple-peel waste helps reduce organic waste and yields environmentally friendly products free of synthetic chemicals. This research demonstrates the synergy between national food-security programs and innovations in waste management, which together contribute to sustainable development and improve the quality of life of the Indonesian people. This research demonstrates the synergy between national food security programs and innovations in waste management, which together contribute to sustainable development and improve the quality of life of the Indonesian people.

Shampoo can help address scalp problems, such as itching caused by dandruff. Dandruff is the most common hair problem, particularly on sensitive scalps.[4] Dandruff is one of the most common scalp disorders, especially in individuals with sensitive scalp conditions. Indonesia, as a tropical country with high humidity, provides favorable conditions for the growth of various microorganisms. One fungus implicated in causing scalp dandruff is *Malassezia furfur*.[5] *Malassezia furfur* is a fungus found on the scalp; with excessive sweating, it will become pathogenic and multiply rapidly. It causes the scalp to become scaly and itchy.[6]

Using modern anti-dandruff shampoos does not always completely reduce or eliminate dandruff in all individuals, as their effectiveness may vary depending on the underlying causes and user conditions. In addition, some chemical compounds in these products may cause side effects in certain users, such as scalp irritation or dryness. However, these effects generally depend on sensitivity and product formulation. Concerns have also been raised about the potential for reduced responsiveness of dandruff-causing fungi with prolonged or improper use of antifungal agents. However, further research is still needed to understand this issue fully. Natural shampoos have become increasingly popular because they are regarded as gentler, more environmentally friendly, and offering fewer synthetic ingredients.[7,8]

Pineapple peels are often overlooked and discarded as waste; however, they have many potential benefits, including antioxidant, antibacterial, and antifungal properties.[9] The development of nanoparticle technology offers an innovative solution for improving the stability, bioavailability, and penetration of active ingredients into deeper layers of the skin, thereby enhancing therapeutic efficacy.[10] This study aims to determine and evaluate the potential of pineapple peel as an anti-dandruff shampoo developed using nanoparticle technology.

Method

Research Design

This study is quantitative and employs a true experimental design. It uses a posttest-only control-group design and examines the anti-dandruff efficacy of pineapple peel extract against *Malassezia furfur* in culture media.

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Place and Time of Research

The study was conducted at the Integrated Pharmacy Laboratory facility of the Bintang Persada Institute of Technology and Health from June to July 2025.

Tool

The instruments and equipment used in this study were: filter paper, mortar and pestle, dropper pipettes (Onemed), tweezers (Onemed), microscope slides (Onelab), analytical balance (Mettler Toledo), oven (Memmert UN55), ultrasonic homogenizer (Biostellar Ultrasonic Cell Disrupter), homogenizer (Diab), airtight containers, filters, Particle Size Analyzer (Fritsch), UV-Vis spectrophotometer (Shimadzu UV-1700), refrigerator (Aqua), stopwatch, drop plate, rotary evaporator (Buchi R-3), hot plate (Thermo), blender (Philips), microscope, and coverslips.

Material

The test material used in this study was pineapple peel (*Ananas comosus* (*L*.) *Merr.*). The material was obtained from pineapple farmers in Tabanan, Bali Province. Plant identification of the pineapple was also performed at the Bandung Institute of Technology (Institut Teknologi Bandung) with determination number: 1903/IT1.C11.2/TA.00/2025.

Procedure

Sample preparation - Identification of the potential of pineapple peel extract as an antifungal agent. - Collection and review of literature related to antifungal activity. - Preparation of pineapple peel simplicia: the peels were washed, dried, and stored as the raw material for extraction.Maceration extraction: the simplisia were extracted by maceration using 96% ethanol as the solvent.

Phytochemical screening. The phytochemical screening stage aims to identify the classes of secondary metabolites present in the extract. These classes include alkaloids, flavonoids, tannins, saponins, steroids/triterpenoids, and glycosides.

Identification is based on color changes and precipitate formation; each class produces a characteristic response with specific reagents. The class of chemical compounds found in pineapple peel that have potential as color-changing agents is characterized as antifungal agents.

Preparation of Nanogel and Shampoo Particle size analysis of the pineapple peel extract showed the formation of small particles using a homogenizer and an ultrasonic homogenizer. The reduction in particle size is influenced by stirring duration and speed: the longer the stirring, the smaller the particles. Shampoo was prepared by mixing SLS, cocamidopropyl betaine, and glycerin, then adding deionized water and incorporating the nanoemulsion of pineapple peel extract at concentrations of 3%, 6%, and 9%. Natural colorants and citric acid were added to adjust the pH, and the mixture was stirred until homogeneous.

Evaluation of the Shampoo Formulation. The evaluations of the formulations in this study included organoleptic observations, pH testing, viscosity testing, foam height measurement, and stability testing.

Transmittance and PSA (Particle Size Analyzer) tests of the shampoo extract. The transmittance test was performed before the PSA test for each concentration. The preparations tested were as follows: F0: blank (no extract); F1: shampoo formulation containing 3% extract; F2: shampoo formulation containing 6% nano-extract; F3: shampoo formulation containing 9% nano-extract. Perform transmittance testing on a spectrophotometer over the wavelength range 400–650 nm. If the results approach or exceed 90%, the extract is suitable for further testing. Perform a PSA (particle size analyzer) test. Test of anti-dandruff activity in shampoo preparations. The activity test

was divided as follows: F0: blank (placebo); F1: shampoo formulation containing 3% extract; F2: shampoo formulation containing 6% extract; F3: shampoo formulation containing 9% extract; positive control: ketoconazole 2%; comparator: Selsun shampoo.

Data Processing and Analysis. Data were analyzed using SPSS to assess differences in anti-dandruff activity and physical stability of shampoo formulations containing ethanol extract of pineapple peel. The data obtained during testing were analyzed by one-way analysis of variance (ANOVA) at a 95% confidence level. The analysis was conducted to determine significant differences among shampoo formulations containing the extract, pineapple peel nanoextract, and nano-formulated shampoo with pineapple peel nanoextract, compared with commercially available shampoos.

Result

Sample Preparation

Macroscopic Examination of Simplisia

Macroscopic observations were conducted by directly examining the physical condition of the pineapple fruit peel used. The results of the macroscopic examination are as follows:

Table 1. Results of Macroscopic Examination of Simplisia

No.	Organoleptic Parameters	Information
1	Shape	Elongated and rounded, wavy with a rough surface, measuring 0.8 cm wide and 9.4 cm long
2	Color	yellowish-brown
3	Smell	Pineapple specialties

Result of Microscopic Observation of Simplisia Powder

Macroscopic examination of the pineapple peel simplicia powder revealed calcium oxalate raphide crystals, meristematic cells, parenchyma with idioblasts containing crystals, epidermis, fibers, and phloem.

Table 2. Results of Microscopic Examination of Simplisia

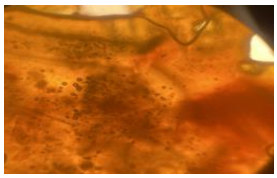
No.	Image Library	Image
1	 Parenkrim	
2	 Stone Cells	

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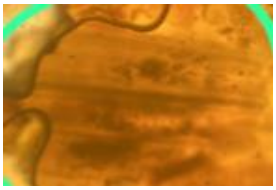
Table 2. (Extension)

No.	Image Library	Image
3	 Calcium Oxalate	

Result of Other Simplisia Characterization Examination

Characterization is an initial step in controlling the quality of simplisia, so that the results can be used as a reference for further research. The characterization of simplisia includes determining moisture content, water-soluble extract content, and ethanol-soluble extract content. The results of the simplisia characterization are presented in Table 3 below.

Table 3. Result of the Simpliasia Characterization

No.	Parameter	Result (%)	MMI (%) requirement
1	Moisture content	2	≤ 10
2	Water-soluble extract content	42,1	≥ 37
3	Ethanol-soluble extract content	25,5	≥ 3

As shown in Table 3, measuring the moisture content of simplisia is intended to determine the maximum limits or range of moisture present in the material. The moisture content of the pineapple peel simplisia was determined to be 2%, meeting the moisture requirement. According to Material Medika Indonesia, the moisture content should not exceed 10%, since excessive moisture can promote microbial growth or enzymatic reactions that may degrade active compounds. Test results showed that the water-soluble extract content of pineapple peel simplicia *(Ananas comosus)* was 42.1%, while the ethanol-soluble extract content was 25.5%.[11]

Extraction Results

The pineapple peel extract was obtained by maceration using 96% ethanol as the solvent. The maceration method is a simple, rapid extraction technique suitable for heat-sensitive compounds. Ninety-six percent ethanol was used because it is a universal solvent capable of extracting both polar and nonpolar compounds. The maceration yielded 55.1 g of extract from 500 g of simplisia (dried plant material), corresponding to a yield of 60.36%; the extract was liquid and dark brown to blackish in color.

Phytochemical Screening Results

Phytochemical analysis was performed on the pineapple peel extract and its nanoparticles to detect secondary metabolites. This test aims to identify groups of compounds, including alkaloids, flavonoids, tannins, saponins, steroids/triterpenoids, and glycosides. The identification process is based on the typical reactions each compound exhibits with a particular reagent, such as the appearance of distinct colors or the formation of characteristic deposits.

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Table 4. Phytochemical Screening Results of Pineapple Peel Extract and Nanoparticle Extract (*Ananas Comosus*)

No.	Chemical Compounds Group	Extract
1	Flavonoids	+
2	Alcolloid	+
3	Saponins	+
4	Tannins	+
5	Glycosides	+
6	Steroids	+

Description:
(+) : contains chemical compounds
(-) : does not contain chemical compounds

Based on Table 4. The results of the phytochemical screening of pineapple peel extracts and nanoextracts are shown above, indicating positive responses to the tested chemical compounds. Positive results were indicated by discoloration upon application of the test solution to each compound.[12]

Manufacture of Nano Emulsion and Shampoo Pineapple Peel Extract

The process of making nanoemulsions has been shown to increase the solubility of pineapple peel extract in a water-based medium, thereby facilitating its incorporation into shampoo formulations. The use of different extract concentrations allowed researchers to compare the effectiveness and stability of the shampoo produced, including pH, viscosity, foam height, and antifungal activity.

The methods for making nanoemulsions, both surfactant-based and high-energy homogenization, can reduce particle (droplet) size to the nanometer range. This increases surface area, improves dispersibility, and allows lipophilic extracts to dissolve better in water-based systems. Pineapple peel extract produced by the nanoemulsion method is safer and more stable for use in topical cosmetic formulations.[13]

Evaluate Shampoo Preparation

Organoleptic Test

The results of organoleptic observations of pineapple peel and dandruff shampoo preparations are shown in Table 5. below.

Table 5. Organoleptic Test Results

Formula	Shape	Colour	Smell
F0	Gel	Clear	odorless
F1	Gel	Yellow	Pineapple Specials
F2	Gel	Light Brown	Pineapple Specials
F3	Gel	Brown	Pineapple Specials

Description:
F0 : Blank
F1: Nanoextract shampoo formulation 3% concentration
F2: Nanoextract shampoo formulation 6% concentration
F3: Nanoextract shampoo formulation 9% concentration

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The results of the organoleptic test of anti-dandruff shampoo with pineapple peel extract were obtained: a gel-textured shampoo that is easy to pour. The higher the concentration of the extract used, the more intense the color of the shampoo preparation is the brown color of the F3 preparation. The brown color is produced from pineapple peel extract. When making shampoo, it is necessary to control the stirring speed to ensure the mixture becomes homogeneous. Sodium lauryl sulfate is slowly mixed with constant stirring to prevent foam formation during shampoo preparation.

PH test

The pH test results were on nanoextract anti-dandruff shampoo preparations and pineapple peel extract shampoo preparations. It can be seen in Table 6 below.

Table 6. PH Test Results of Pineapple Peel Shampoo

Formula	P1 (pH)	P2(pH)	P3(pH)	Average (SD)
F0	7,5	7,3	7,2	7,3±0.153
F1	6,0	5,9	5,95	5,95±0,050
F2	6,2	6,3	6, 25	6,25±0,050
F3	6,3	6,4	6,25	6,3±0,076

Description:
F0 : Blank
F1: Nanoextract shampoo formulation 3% concentration
F2: Nanoextract shampoo formulation 6% concentration
F3: Nanoextract shampoo formulation 9% concentration

The pH test is an important parameter in the development of shampoo preparations because it is directly related to safety, effectiveness, and comfort of use. The appropriate pH can maintain scalp and hair health and prevent irritation. Normal pH ranges from 4.5 to 6.5. The appropriate shampoo pH helps maintain this layer's function, thereby protecting the scalp from pathogenic microbes and preventing dryness.

Viscosity Test

Viscosity is the resistance of a liquid to flow. Viscosity testing is done to measure the shampoo's viscosity. Viscosity measurement using a viscometer with spindle 4 at 50 rpm. Viscosity test results on pineapple peel nanoextract anti-dandruff shampoo. It can be seen in Table 7 below.

Table 7. Viscosity Test Results of Nano Shampoo Preparations

Formula	P1 (cps)	P2 (cps)	P3 (cps)	Average (SD)
F0	2850	2870	2865	2861,67 ± 10,41
F1	2930	2960	2980	2956,67 ± 25,17
F2	3031	3078	3056	3055,00 ± 23,52
F3	3156	3138	3168	3154,00 ± 15,10

Description :
F0 : Blank
F1: Nanoextract shampoo formulation 3% concentration
F2: Nanoextract shampoo formulation 6% concentration
F3: Nanoextract shampoo formulation 9% concentration

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Results of Table 7. It shows that the viscosity of shampoo preparations varies due to the addition of extracts and nanoextracts. The lowest viscosity is at F0 (2861.67 cps), with a slightly viscous consistency, while the highest is at F3 (3154.00 cps), which uses nanoextracts and is affected by stirring time.[14] All formulas still meet good shampoo viscosity standards (400–4000 cps).[15] V Too high a viscosity indicates a lower water content, making the shampoo more difficult to pour and reducing user comfort.

Table 8. Foam Height Test

Formula	High Initial Foam (Cm)	High Form After 5 minutes (Cm)	Stability (%)
F1	3,8	3,2	84,2
F2	4,5	3,9	86,7
F3	5,2	4,5	86,5
Pembanding	6,0	5,5	91,7

Description:
F0 : Blank
F1: Nanoextract shampoo formulation 3% concentration
F2: Nanoextract shampoo formulation 6% concentration
F3: Nanoextract shampoo formulation 9% concentration

The results showed that the pineapple peel extract shampoo achieved a fairly good height, close to that of the commercial shampoo, although slightly lower. Formulas with a concentration of 9% produce higher foam than low concentrations. The stability of the foam is in the range of 84–86%,[16] which is good, as it maintains its structure after 5 minutes.

Nanoemulsion Transmittant Test Results and PSA (Particle size analyzer) Test Results of Pineapple Peel Extract

Wavelength 650 nm. The transmitter value (%T) is used to assess the clarity of the nanoemulsion preparation. The higher the %T-value, the clearer the preparation will be. Clarity may affect the feasibility of the Particle Size Analyzer (PSA) test. The results of the Transmittance Test are shown in Table 9 below.

Table 9. Transmitter Test of Pineapple Peel Shampoo Preparation

Code Sample	Repetition1	Repetition 2	Repetition 3	Avarage (SD)
F1	92,3	92,5	92,1	92,3± 0,2
F2	94,8	95,1	94,9	94,9 ± 0,2
F3	96,5	96,8	96,2	96,6 ± 0,2

Description:
F0 : Blank
F1: Nanoextract shampoo formulation 3% concentration
F2: Nanoextract shampoo formulation 6% concentration
F3: Nanoextract shampoo formulation 9% concentration

All formulas have a transmitter value above 90%, indicating excellent clarity according to the nanoemulsion criteria. The F3 formula shows the highest clarity (96.5%), likely due to an optimal surfactant-to-oil ratio, which results in smaller, more uniform droplets. A low standard deviation (<0.5) indicates consistent measurement. The high

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transmitter indicates that the droplet size of the nanoemulsion is very small, generally less than 800 nm.

In the particle size test of pineapple peel extract, a small particle size was obtained. This happens because it goes through the Homogenizer and Ultrasonic Homogenizer processes. Small particle size results from the length and speed of stirring. The longer the stirring, the smaller the particle size will be because more particles are broken down into nanosized particles.[17]

The transmitter test on nanoemulsions is used to determine the preparation's clarity by measuring the percentage of light passing through the sample. A high transmitter value (usually >90%) indicates that the formed nanoemulsion system is clear, optically stable, and very small in particle size. However, the results of the transmitter test provide only qualitative information on clarity, without specifying the exact particle size or size distribution. The PSA (Particle Size Analysis) test is carried out as an advanced stage to determine the particle size quantitatively. The results of the PSA (Particle size analyzer) test are shown in Table 10. Below

Table 10. PSA (Particle Size Analyzer) Results of Pineapple Peel Shampoo Preparation

Code	Z-Average (nm)	PDI	Zeta Potential (mV)	Peak Intensity(%)	Peak Width (nm)
F1	168.4 ± 5.2	0.241 ± 0.018	−31.6 ± 1.9	96.8 ± 0.7	62 ± 5
F2	132.7 ± 3.8	0.196 ± 0.012	−34.8 ± 2.3	97.9 ± 0.5	49 ± 4
F3	92.5 ± 2.9	0.148 ± 0.010	−36.1 ± 1.7	98.6 ± 0.4	37 ± 3

Description:
F0 : Blank
F1: Nanoextract shampoo formulation 3% concentration
F2: Nanoextract shampoo formulation 6% concentration
F3: Nanoextract shampoo formulation 9% concentration

PSA (particle size analysis) and zeta potential measurements were performed in triplicate to obtain accurate, consistent, and statistically reproducible results, thus meeting accepted standards for replication. The particle size of the entire formula is in the nano-range (≈90–170 nm), as per the nanoemulsion target. The PDI < 0.25 indicates a narrow size distribution; F3 is the most homogeneous (PDI ~0.15). Zeta potential ≤ −30 mV in all formulas indicates good electrostatic stability; F3 is most stable (≈−36 mV). The intensity spectrum shows one dominant peak (>96%) with no significant agglomeration. F3 is the best formula based on the combination of the smallest size, the lowest PDI, and the most negative zeta. The results showed that droplets with a size of <200 nm were able to expand the contact surface area, thereby increasing the penetration effectiveness of active ingredients in topical and oral applications.[18] These findings are in line with research that zeta potentials below −30 mV are sufficient to provide good stability to nanodispersion systems.[19] In addition, the intensity spectrum showed one dominant peak (>96%) in the absence of significant agglomeration, which confirmed that the nanoemulsion system was well formed and no phase separation occurred.

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Test Anti-Dandruff Activity on Shampoo Preparations

Table 11. Anti-Dandruff Test Results of Pineapple Peel Shampoo

Formula	Buffer Zone			
	P1 (mm)	P2 (mm)	P3 (mm)	Avarage
F0	2,1	1,7	1,8	1,86
F1	18,5	19,75	20,25	19,5
F2	20,2	20,3	18,75	19,75
F3	22,2	23,35	22,3	22,6
Kontrol+	23,95	22,8	21,95	22,9
Pembanding	19,7	19,35	19,75	19,6

Description:
F0 : Blank
F1: Nanoextract shampoo formulation 3% concentration
F2: Nanoextract shampoo formulation 6% concentration
F3: Nanoextract shampoo formulation 9% concentration
Control (+) : Ketokonazol 2%
Comparator: Selsun shampoo

Based on Table 11, the F3 formula shows the largest inhibition zone compared to F1 and F2, with an average of 22.6 mm, while F1 and F2 have 19.5 mm and 19.75 mm, respectively. The inhibition zone in the blank was only 1.86 mm, the positive control (ketoconazole) was 22.9 mm, and the comparative sample was 19.6 mm. This data shows that the nanoextract of pineapple peel *(Ananas comosus)* formulated into the shampoo can inhibit the growth of *Malassezia furfur*. This effect is thought to come from the content of secondary metabolites that act as antifungals.[20] The antifungal activity of shampoo formulated from pineapple peel primarily arises from secondary metabolites—such as flavonoids, saponins, tannins, and bromelain—that can inhibit fungal growth by damaging cell membranes and disrupting fungal metabolism.[21]

Data Analysis

Based on Table 10, the diameter of the inhibition zone of each formula can be calculated. The diameter of the inhibition zone for each shampoo formula varies according to the results of SPSS One-Way ANOVA (ANOVA) at a 95% confidence level, with a significance level of 0.00. The data show that the resulting inhibition zone is quite significant, indicating a significant difference between each shampoo formula made from pineapple peel nanoextract at concentrations of 3%, 6%, and 9% and commercial shampoos.

Discussion

Research shows that pineapple peel extract has superior initial quality: good organoleptic properties, low moisture content (2%), and high yield (60%). The literature reports similar results for fruit peel-based cosmetic formulations (such as shampoos from pineapple and celery peels) that exhibit homogeneity and good panelist acceptance.[22] This moisture content range also supports long-term stability within the ideal range of dry extracts in encapsulation studies.[23] Meanwhile, the yield of 60% is close to the optimal efficiency as reported in mango peel extract (≈62.9%) and the depth of pineapple peel extract using strengthening techniques.[24]

The results showed that the nanoemulsions underwent a visual change from cloudy to clear. This phenomenon reflects the successful formation of nanometer-sized (20–200 nm) droplets with homogeneous dispersion. The clarity of the nanoemulsion

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indicates a uniform, physically stable particle-size distribution.[25] Similarly, it is reported that the transparency in nanoemulsions is caused by a decrease in droplet size so that the light scattering is significantly reduced.[26]

Gel shampoo made from pineapple peel extract has an easy-to-pour texture, thanks to its formulation with natural thickening ingredients, providing comfort in use.[27] Increased concentration of the extract results in a more concentrated color (brown) derived from phenolic pigments and tannins, a common phenomenon in herbal preparations.[28] pH value of 4.5–6.5 indicates a safe condition and is in accordance with the physiological pH of the scalp, so it does not cause irritation.[29] The viscosity of 2,861–3,154 cps indicated a slightly viscous and stable consistency, with the increased viscosity in the formula with nanoextracts attributable to the stirring process and the concentration of the active ingredients.[29] In addition, the stability of the foam of 84–86% was considered good because the foam could still last after 5 minutes, according to reports on herbal shampoo formulations, which generally have quite high foam stability even without synthetic surfactants.[30]

In the particle size test of pineapple peel extract, a small particle size was obtained. This happens because it goes through the Homogenizer and Ultrasonic Homogenizer processes. Stirring was carried out with a homogeniser for 30 minutes at 1500 rpm, followed by ultrasonication for 30 minutes at 40 kHz. Small particle size results from the length and speed of stirring. The longer the stirring, the smaller the particle size will be because more particles are broken down into nanosized particles.[17] The results of the study showed that the PSA size had reached a dominant peak (>96%), which showed quite good results. Research shows that droplets with a size of <200 nm can expand the surface area of contact, thereby increasing the penetration effectiveness of active ingredients in topical and oral applications.[18] These findings are consistent with studies showing that zeta potentials below −30 mV are sufficient to provide good stability to the nano-dispersion system.[19] In addition, the intensity spectrum shows one dominant peak (>96%).

Research on nanoextracts of pineapple peel *(Ananas comosus)* formulated into shampoo shows they can inhibit the growth of *Malassezia furfur*. These results are consistent with previous studies showing that plant extracts, including those from fruits such as pineapple, have antifungal activity against Malassezia spp. and, in many cases, are as effective as commercial anti-dandruff shampoos. This indicates that the nanoformulation of pineapple peel extract has the potential to be an effective alternative to natural ingredients in the development of anti-dandruff shampoos. This effect is thought to come from the content of secondary metabolites that act as antimicrobials.[20] The results of the One-Way ANOVA test ($\alpha = 0.05$) showed a significance value of $p = 0.00$, indicating a significant difference between pineapple peel nanoextract shampoo with concentrations of 3%, 6%, and 9% compared to commercial shampoos. This shows that the extract concentration has a noticeable effect on the preparation's effectiveness.

Conclusion

Shampoos formulated with nanoextracts from pineapple peels *(Ananas comosus)* met the quality requirements of SNI 06-2692-1992. Organoleptic tests showed no changes in color, appearance, or odor among the three formulations. pH values were within the SNI standard range for shampoos (5.0–9.0), and viscosities ranged from 400 to 4,000 cps. Foam height tests indicated good, stable foam, and moisture content was below the maximum limit of 95%. Cleansing power ranged from 32–66%; the higher the percentage, the more effective the shampoo is at removing dirt and oil. All formulations demonstrated anti-dandruff activity against *Malassezia furfur*, with formulations 1, 2, and 3 showing strong antifungal activity. Overall, this shampoo has the potential to be a more environmentally friendly natural alternative to synthetic shampoos.

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