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Antioxidant Activity and Stability of Chinese Betel Leaf Extract Lotion Preparation *(Peperomia pellucida)* as a Skin Moisturizer

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Abstract
Skin is highly susceptible to damage from ultraviolet exposure, environmental pollution, and free radicals, which accelerate premature aging and skin dryness. Peperomia pellucida (Chinese betel) leaves contain secondary metabolites—flavonoids, tannins, saponins, alkaloids, and steroids—that are potential sources of natural antioxidants. This laboratory-based experimental study aimed to formulate P. pellucida leaf extract into a lotion and to evaluate its antioxidant activity, physical stability, and moisturizing effectiveness. The extract was obtained by maceration in 70% ethanol and formulated into three concentrations (2%, 3%, and 5%). Evaluations included organoleptic, homogeneity, pH, spreadability, adhesiveness, viscosity, emulsion-type, irritation, skin-moisture (skin analyzer), hedonic, and DPPH antioxidant assays; stability was assessed through a six-cycle cycling test. The extract tested positive for flavonoids, tannins, saponins, alkaloids, and steroids, with an IC50 of 8.995 µg/mL (very strong category). The three lotion formulas were homogeneous, physically stable, oil-in-water (O/W) emulsions, with post-cycling pH ranging from 7.29–7.92. The IC50 values of lotions F1, F2, and F3 were 24.704, 22.464, and 21.231 µg/mL, respectively (strong category), while the moisturizing test showed a significant increase in skin hydration ($p < 0.05$) without causing irritation. It is concluded that P. pellucida leaf extract can be formulated into a stable lotion with strong antioxidant activity and effective moisturizing properties.

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1. INTRODUCTION

The development of modern lifestyles along with the currents of globalization has driven an increasing demand for skincare and cosmetic products. Cosmetics are defined as substances or preparations applied to the external parts of the human body to cleanse, enhance appearance, and maintain good body condition. The skin, as the outermost organ that is directly exposed to the environment, is susceptible to damage from exposure to ultraviolet light, pollution, lack of sleep, dehydration, and free radicals. This exposure can trigger premature aging, age spots, dullness, dryness, and even impaired skin barrier function.

Free radicals are reactive molecules with an unpaired electron in their outer orbital, making them unstable and easily bonding with other molecules to achieve stability, including skin cell components such as membrane lipids and structural proteins. Antioxidants stabilize free radicals by donating one or more electrons, thus inhibiting their reactivity. Because the body's endogenous antioxidant reserves are limited, exogenous antioxidant intake, whether through food, supplements, or topical preparations, is essential to complement the defense system against oxidative stress.

The public's trend of switching from synthetic cosmetics to natural ones is driven by concerns about the side effects of synthetic ingredients and increasing awareness of safer products. One local plant with potential as a source of natural antioxidants is the Chinese betel leaf (*Peperomia pellucida*), a wild plant with soft, high-water content that is easily found in humid environments in Indonesia. Traditionally, this plant has been used as a remedy for gout, arthritis, and inflammation, and is known to contain flavonoids, terpenoids, saponins, and tannins that act as natural antioxidants.

Previous research reported that 70% ethanol extract of Chinese betel leaves had an IC50 value of 24.51 µg/mL, which is classified as very strong, considering that the smaller the IC50 value, the greater the free radical inhibition capacity. This finding opens up opportunities for the use of Chinese betel leaf extract in topical pharmaceutical preparations, one of which is lotion preparations. Lotion is a cosmetic preparation of the emollient group with a liquid consistency with a higher water phase content than the oil phase, so it is easy to spread evenly on the skin surface, dries quickly after application, and does not leave a greasy impression, but still provides a moisturizing effect and a protective layer similar to the skin's natural sebum.

In addition to pharmacological activity, the physical quality and stability of a preparation are crucial aspects that determine the suitability of a product before its widespread production. A preparation is considered stable if its active ingredient content does not decrease significantly and does not show any organoleptic changes, such as color, odor, shape, or microbial contamination, during storage. Accelerated stability testing through the cycling test method, which simulates repeated extreme temperature variations, is commonly used to predict the behavior of a preparation under real-world storage conditions over a shorter period.

Although the antioxidant potential of Chinese betel leaf extract has been reported, studies on its formulation into a multifunctional lotion preparation that simultaneously evaluates its antioxidant activity, physical stability, and moisturizing effectiveness in an integrated manner are still limited. Based on this description, this study aims to: (1) determine the antioxidant activity of Chinese betel leaf extract after being formulated into a lotion preparation; (2) evaluate the physical stability of the lotion preparation during accelerated storage; and (3) determine the effectiveness of the lotion preparation in increasing skin moisture. The results of this study are expected to provide scientific contributions to the development of safe, stable, and effective natural cosmetics.

2. RESEARCH METHODS

This research is an experimental laboratory study conducted at the Pharmaceutical Laboratory of Duta Bangsa University, Surakarta, in May–June 2026. The main material used is fresh Chinese betel leaves obtained from Pakis Village, Magelang, Central Java, and were determined at the Functional Service Unit of Tawangmangu Traditional Health Services, Dr. Sardjito General Hospital. Supporting materials include 70% ethanol, stearic acid, triethanolamine (TEA), liquid paraffin, cetyl alcohol, propylene glycol, butyl hydroxytoluene (BHT), nipagin, nipasol, and distilled water. The tools used include a skin analyzer (MSH Medic), a rotary evaporator, an oven, a No. 40 mesh sieve, a pH meter, a moisture balance, a Brookfield viscometer, a UV-Vis spectrophotometer, and an analytical balance.

The independent variables in this study were variations in the concentration of Chinese betel leaf extract (2%, 3%, and 5%), while the dependent variables included the results of the physical evaluation of the preparation (organoleptic, emulsion type, pH, homogeneity, spreadability, adhesiveness, viscosity), antioxidant activity, and effectiveness of skin moisture.

Preparation and Standardization of Simple Drugs

Fresh Chinese betel leaves were wet-sorted, washed, chopped, dried, protected from direct sunlight, dry-sorted, ground, and sieved using a No. 40 mesh sieve to obtain a simple powder [8]. Standardization of the simple includes organoleptic tests and determination of drying loss, water content, and ash content using a moisture balance and oven heating method, referring to the parameters of the Herbal Pharmacopoeia.

Extract Preparation and Standardization

The extract was obtained through maceration of 500 g of simplicia powder with 70% ethanol solvent (ratio 1:10) for 3 × 24 hours, protected from light while occasionally stirring, filtered, then concentrated using a rotary evaporator until a thick extract was obtained. The extract was then standardized, including organoleptic, water content gravimetric method, ethanol-free test, and metal contamination test (Pb and Cd).

Phytochemical Screening

Phytochemical screening was carried out using a test tube to detect alkaloids (Mayer and Dragendorff reagents), flavonoids, tannins, saponins, and steroids/triterpenoids in the extract.

Antioxidant Activity Test (DPPH Method)

The antioxidant activity of the extract and lotion preparation was measured using a UV-Vis spectrophotometer based on the inhibition of DPPH radicals (1,1-diphenyl-2-picrylhydrazyl) at the maximum absorption wavelength, with vitamin C as a comparison. The % inhibition value was calculated from the difference in absorbance of the blank and sample, and the IC50 value was determined through a linear regression equation of the concentration curve against % inhibition.

Lotion Preparation Formulation

The lotion formulation refers to the modified formula of Syaputri et al. with variations in extract concentration of 2% (F1), 3% (F2), and 5% (F3), as presented in Table 1. The oil phase (stearic acid, cetyl alcohol, liquid paraffin, BHT, nipasol) and the water phase (aquadest, extract, propylene glycol, TEA, nipagin) were each heated at 80 °C, then mixed and stirred until homogeneous to form a lotion emulsion.

Material	F1 (%)	F2 (%)	F3 (%)	Function
Chinese betel leaf extract	2	3	5	Active ingredient
Stearic acid	1	1,5	2	Emulsifier
TEA	2	3	4	Emulsifier
Liquid paraffin	1	1	1	Emollient
Setil alcohol	6	6	6	Stiffening agent
Propylene glycol	5	5	5	Humectant
BHT	0,01	0,01	0,01	Oxidation inhibitors
Nipagin	0,15	0,15	0,15	Preservative
Nipasol	0,05	0,05	0,05	Preservative
Aquadest	ad 100 mL	ad 100 mL	ad 100 mL	Solvent

Table 1. Formulation of Chinese Betel Leaf Extract Lotion Preparation

Evaluation of Physical Quality and Stability of Preparations

Physical quality evaluation includes organoleptic tests, homogeneity, pH (calibrated pH meter), spreadability, adhesiveness, viscosity (Brookfield viscometer, spindle No. 7, 10 rpm), and emulsion type (methylene blue staining), referring to Syaputri et al. and Juniyanti et al. [12]. Physical stability testing was carried out through a cycling test, namely alternating storage at 40 °C and 4 °C for six cycles (12 days), with physical quality evaluation in each cycle.

Humidity, Hedonic, and Irritation Tests

The moisturizing effectiveness was tested on 15 healthy-skinned volunteers using a skin analyzer for 7 consecutive days of use; a moisture value <40 indicates insufficient moisture, while 40–60 indicates adequate moisture. Hedonic testing was performed on color, aroma, texture, and ease of application using a scale of 1–5. Irritation testing was performed based on the appearance of redness, itching, or swelling on the panelists' skin.

Data analysis

Data on antioxidant activity and physical quality were analyzed descriptively and quantitatively and presented in tables and graphs. Moisture test data were analyzed using a Repeated Measures ANOVA (α = 0.05) statistical test to determine differences in effects between formulas.

3. RESEARCH RESULTS AND DISCUSSION

3.1 Research Results

The research results are presented briefly, including standardization of simplicia and extracts, phytochemical screening, antioxidant activity, evaluation of the physical quality of the preparation, stability test, humidity test, hedonic test, and irritation test.

Parameter	Results	Quality Requirements	References
Simplex yield	16,0%	-	[6]
Drying shrinkage of simple drugs	7,3 ± 0,60%	< 10%	[6]
Water content of simple drugs	4,7 ± 0,23%	< 10%	[6]
Ash content of simple drugs	0,7 ± 0,05%	< 37,8%	[6]
Yield of thick extract	21,4%	≥ 13,1%	[6]
Extract water content	3,72 ± 0,02%	< 15,2%	[6]
Ethanol free test	Negative	Ethanol free	-
Metal contamination (Pb, Cd)	Negative	Free from contamination	-

Table 2. Standardization of Simplicia and Chinese Betel Leaf Extract

Compound Groups	Results
Alkaloid	+
Flavonoid	+
Saponin	+
Land	+
Steroid/Triterpenoid	+

Table 3. Phytochemical Screening Results of Chinese Betel Leaf Extract (+ = detected)

The operating time test results showed that the absorbance of the DPPH solution was stable at 15 minutes, so it was used as the incubation time for the measurements. The IC50 values of the extract, vitamin C as a comparison, and the three lotion formulas are presented in Table 4 and Figure 1.

Sample	IC50 (µg/mL)	Category
Chinese betel leaf extract	8,995	Very strong
Vitamin C (comparator)	6,455	Very strong
Lotion F1 (2% extract)	24,704	Strong
Lotion F2 (3% extract)	22,464	Strong
Lotion F3 (extra 5%)	21,231	Strong

Table 4. IC50 Values of Extracts, Vitamin C, and Lotion Preparations

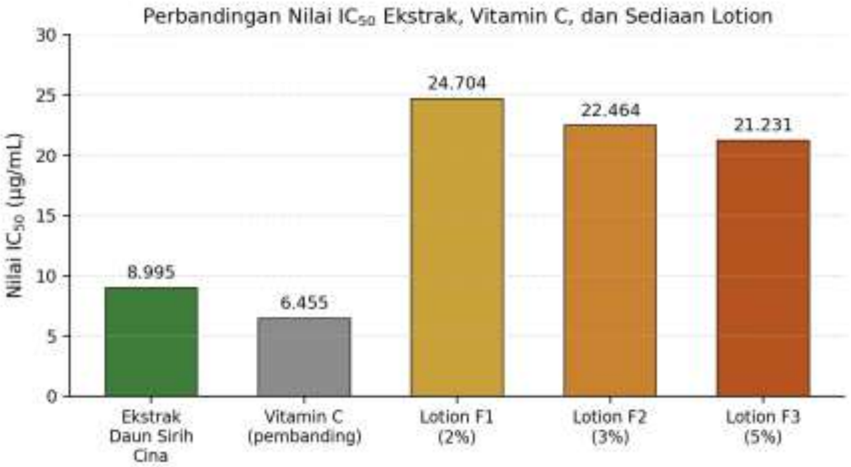

Figure 1. Comparison of IC50 Values of Extract, Vitamin C, and Lotion Preparations

Evaluation of the physical quality of the lotion preparation before and after the six-cycle cycling test is presented in Table 5. In general, the three formulas remained homogeneous and were in the form of oil-in-water (O/W) type emulsions throughout the test cycles.

Parameter	Early F1	F1 final	F2 awal	F2 akhir	F3 awal	F3 akhir
pH	8,27±0,14	7,37±1,20	8,30±0,06	7,56±1,12	8,59±0,18	7,66±1,06
Adhesion (seconds)	4,55±0,38	4,51±0,60	8,57±0,06	4,61±0,52	8,79±0,18	4,55±0,53
Spread power (cm)	7,22±0,05	7,16±0,44	7,26±0,18	7,23±0,34	8,13±0,19	7,30±0,46
Viscosity (cPs)	2254±236	4384±2217	2356±233	5082±2326	2451±386	4539±2239
Homogeneity	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous
Emulsion type	M/A	M/A	M/A	M/A	M/A	M/A

Table 5. Evaluation of the Physical Quality of Lotion Preparations Before and After the Cycling Test

The results of the skin moisture effectiveness test for 7 days of use, the hedonic test on 15 panelists, and the irritation test are presented in Table 6 and Figure 2.

Formula	Δ Humidity (%) ± SD	P-value	Hedonic Score	Irritation (n=15)
F1 (2%)	11,925 ± 4,192	0,038*	4,10	0/15
F2 (3%)	11,945 ± 4,204		4,02	0/15
F3 (5%)	12,695 ± 4,699		4,03	0/15

Table 6. Results of Humidity, Hedonic, and Skin Irritation Tests (*significant at p<0.05, Repeated Measures ANOVA)

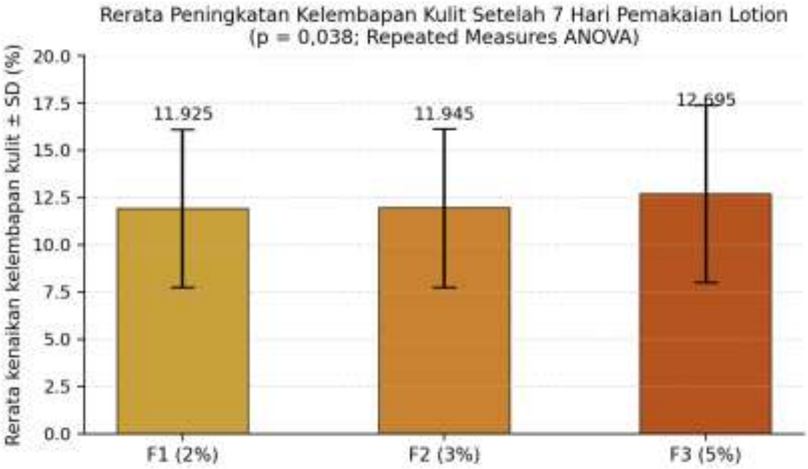

Figure 2. Average Increase in Skin Moisture After 7 Days of Lotion Use

3.2 Discussion

Determination and Preparation of Simple Ingredients

Plant identification is a crucial initial step in ensuring the botanical identity of the samples used, thus minimizing the risk of errors in raw material collection and the possibility of mixing with other species with similar morphology. The determination results at the Tawangmangu Traditional Health Services Functional Unit, Dr. Sardjito General Hospital, confirmed that the samples used were indeed the Peperomia pellucida species, thus ensuring the scientific validity of the data generated in subsequent research stages.

The yield of 16.0% of the simplicia indicates the efficiency of the sorting, washing, drying, and refining processes that have been carried out according to standard procedures. The drying loss value (7.3 ± 0.60%) and water content (4.7 ± 0.23%), which are far below the 10% threshold, indicate that the simplicia have been sufficiently dried so that the risk of microbial growth or chemical degradation during storage is relatively low. The low ash content (0.7 ± 0.05%) also indicates minimal inorganic or mineral impurities, which indicates good purity of the simplicia and an effective pre-drying washing process.

Extraction and Extract Yield

The maceration method was chosen because of its simple working principle and no heating involved, so that the thermolabile secondary metabolites in Chinese betel leaves, especially flavonoids and phenolic compounds, do not experience structural damage due to high temperatures during the extraction process. The use of 70% ethanol solvent is based on its semipolar properties that can optimally attract polar and semipolar compounds, while also having a better safety profile compared to other organic solvents for applications in the pharmaceutical and food sectors.

The yield of the thick extract obtained was 21.4%, which met the quality requirements for the yield of Chinese betel leaf extract, which was set at no less than 13.1% [6]. This high yield value indicates that most of the active compounds soluble in ethanol were successfully extracted during the maceration process, in line with the relatively low initial water content of the simplicia, so that it did not hinder the solvent diffusion process into the plant cell matrix. Further extract standardization results showed a water content of 3.72 ± 0.02%, far below the maximum limit of 15.2%, so the risk of microbial contamination and a decrease in the quality of the extract during storage was relatively small. The ethanol-free test and the metal contamination test, both of which showed negative results, further strengthen the conclusion that the resulting extract meets the safety criteria as a raw material for topical preparations.

Phytochemical and Bioactive Compound Screening

Phytochemical screening results showed that the Chinese betel leaf extract contained alkaloids, flavonoids, saponins, tannins, and steroids/triterpenoids (Table 3). The presence of alkaloids was indicated by the formation of a precipitate with Mayer and Dragendorff reagents, which occurs because the free nitrogen group in the alkaloid is able to bind heavy metal ions to form a precipitate complex. Positive flavonoid results were indicated by a red-orange color change in the reduction reaction with magnesium powder and hydrochloric acid, indicating the presence of flavonoid groups with a distinctive phenolic framework. Flavonoids play an important role as antioxidants, antimicrobial agents, and ultraviolet radiation filters in plant tissues.

The formation of stable foam in the saponin test indicates the amphiphilic glycoside nature of the compound, which is able to form micelles/foam in an aqueous medium through the hydrolysis process into glucose and its aglycone. The positive reaction of tannin with $FeCl_3$, which produces a blackish-green color, indicates a condensed tannin group, formed due to the interaction of the phenolic hydroxyl group in tannin with iron(III) ions. The positive result of steroids/triterpenoids is indicated by a green color change in the modified Liebermann–Burchard reaction (CH_3COOH and concentrated H_2SO_4), which occurs due to the oxidation of functional groups in the steroid ring framework. The diversity of these bioactive compound groups is consistent with the phytochemical profile of P. pellucida that has been reported in previous genetic and taxonomic studies of this plant, which confirm the presence of flavonoids and phenolic compounds as characteristic of the species.

Antioxidant Activity of Extract

The DPPH method was chosen due to its procedural simplicity, analytical speed, and sensitivity in detecting the hydrogen atom donor capacity of a compound. Its mechanism of action is based on the reduction of the dark purple DPPH radical to a stable, pale yellow diamagnetic form, following the donation of hydrogen atoms from antioxidant compounds to the sample. The intensity of this color change is measured quantitatively using a UV-Vis spectrophotometer at the maximum DPPH absorption wavelength.

The extract of Chinese betel leaf showed an IC50 value of 8.995 µg/mL, which is classified as very strong (IC50 <50 µg/mL), even approaching the activity of vitamin C as a positive control (IC50 6.455 µg/mL), which has a free hydroxyl group as a highly reactive hydrogen atom donor. This similarity in order of magnitude indicates that the total phenolic compound content in the extract, especially flavonoids and tannins, plays a dominant role as an effective free radical scavenging agent. The IC50 value obtained in this study is even lower (stronger) than the results of previous studies on 70% ethanol extract of Chinese betel leaf, which reported an IC50 of 24.51 µg/mL. This difference can be explained by various factors, such as the geographical location and agro-climatic conditions where the plant grows, harvest age, drying method, solvent-to-solids ratio, and maceration time, all of which affect the levels and profiles of extracted secondary metabolite compounds.

Formulation and Evaluation of the Physical Quality of Lotion Preparations

The lotion formulation process is carried out using the heat emulsification method, where the oil phase (stearic acid, cetyl alcohol, liquid paraffin) and the water phase (aquadest, propylene glycol, TEA) are each heated to 80 °C before being mixed. The equality of the two phases' temperatures during mixing aims to prevent premature solidification of lipophilic components such as cetyl alcohol and stearic acid, so that the emulsifier can work optimally to form fine and homogeneous dispersed phase droplets. The extract is added after the mixture temperature has decreased to minimize the risk of thermal degradation of thermolabile flavonoid and phenolic compounds.

The organoleptic test results showed that the intensity of the yellow color in the preparation increased with increasing extract concentration, from light yellow in F1 to brownish yellow in F3, in line with the natural color of thick Chinese betel leaf extract containing chlorophyll pigments and phenolic compounds. All three formulas remained homogeneous before and after the cycling test, indicating that the mixing of the oil and water phases took place perfectly without the formation of coarse particles or aggregates that settled. However, after six cycles of the cycling test, the texture of the preparation tended to be slightly thinner than the initial condition, a phenomenon consistent with the results of the viscosity test, which changed after the extreme temperature cycle.

The pH value of the preparation before the cycling test ranged from 8.27–8.59, which is above the normal skin pH range (4.5–6.5) and therefore potentially uncomfortable when applied directly to sensitive skin. Interestingly, after six cycles of cycling, the pH value decreased to 7.29–7.92, approaching the neutral to slightly alkaline range that is more tolerable to the skin. This decrease is thought to be related to the partial hydrolysis of fatty acids in the oil phase of the preparation (especially stearic acid) due to repeated exposure to high temperatures during the heat–cold cycle, which produces free fatty acids and gradually decreases the pH value. Although this trend indicates that the preparation is moving closer to the ideal range, the initial pH value, which tends to be alkaline, remains an important note for further formula optimization, for example by adjusting the proportion of triethanolamine as a neutralizing base in the stearic acid–TEA anionic emulsifier system.

The adhesion test showed that all formulas had adhesion times below 4 seconds in each test, meeting the adhesion quality criteria for topical preparations, so that the preparation was easy enough to apply but still had adequate contact time with the skin to provide the desired effect. The spread ability test ranged from 7.16–8.13 cm, slightly above the ideal range of 5–7 cm generally required for topical semisolid preparations, indicating a lotion consistency that tends to be medium-liquid so that it is easy to spread evenly on the skin surface without requiring large application pressure.

The viscosity value before the cycling test ranged from 2,254–2,451 cPs and increased to 4,384–5,082 cPs after six cycles, but remained within the required viscosity range for lotion preparations (2,000–50,000 cPs). The increase in viscosity after the cycling test can be explained by the mechanism of the reduction in the size of the dispersed phase droplets due to repeated mechanical stress during extreme temperature changes, which increases the surface area of contact between phases and strengthens the structural interaction of the emulsion network, so that particle movement becomes more inhibited and the viscosity of the preparation increases. The emulsion type test with methylene blue dye consistently showed an oil-in-water (O/W) emulsion type in all formulas, both before and after the cycling test, in accordance with the target formulation of lotion preparations, which are generally based on a continuous water phase to feel light and not greasy when applied to the skin.

Antioxidant Activity of Lotion Preparations

The IC50 values of the three lotion formulas (21,231–24,704 µg/mL) are classified as strong, although numerically higher than the IC50 of the pure extract (8,995 µg/mL). This decrease in potency is a common phenomenon when an extract is formulated into a topical preparation base, caused by the dilution effect due to the addition of various excipients (emulsifiers, humectants, preservatives, and oil phases), which reduce the effective concentration of active compounds per unit volume of the preparation, as well as the possibility of physicochemical interactions between phenolic compounds and lotion matrix components, which slightly limit the accessibility of their active groups to DPPH radicals.

Nevertheless, the consistent pattern of decreasing IC50 values as the extract concentration increases from F1 (24.704 µg/mL) to F2 (22.464 µg/mL) to F3 (21.231 µg/mL) indicates a logical and predictable dose–response relationship: the higher the proportion of bioactive compounds formulated, the lower the resulting IC50 value, meaning the free radical scavenging capacity increases. The consistency of this trend confirms that the formulation process does not eliminate the extract's intrinsic antioxidant activity, but only decreases its intensity proportionally to the active ingredient levels used, so that the formula with the highest extract concentration (F3) has the potential to provide the most optimal topical antioxidant protection.

Moisture Effectiveness, Consumer Acceptance, and Preparation Safety

The results of the moisture test showed a significant increase in skin hydration after seven days of use in all formulas, with the highest average moisture difference value obtained in F3 (12.695 ± 4.699%), followed by F2 (11.945 ± 4.204%) and F1 (11.925 ± 4.192%). The statistical analysis of Repeated Measures ANOVA produced a significance value of $p = 0.038$ ($p < 0.05$), indicating that the difference in moisturizing effects between formulas was statistically significant. This tendency is pharmacologically logical because the higher the concentration of extracts containing natural humectant compounds and antioxidants, the greater the capacity of the preparation to inhibit transepidermal water loss and protect the skin's lipid barrier from oxidative damage, so that skin moisture retention increases more optimally.

The results of the hedonic test on 15 panelists showed that F1 obtained the highest overall average score (4.10) with the best preference in color, texture, and ease of application parameters, while F3 was most preferred in terms of aroma. This pattern indicates a trade-off between the higher concentration of active ingredients (providing stronger moisturizing and antioxidant effects) and consumer sensory preferences, because the more concentrated color and aroma of the extract in F3 slightly reduced panelist acceptance compared to F1, which had milder sensory characteristics. The results of the irritation test were all negative on 15 panelists (no redness, itching, or swelling) in all three formulas, confirming the safety profile of the Chinese betel leaf extract lotion preparation for short-term topical use, so this formula has the potential to be further developed as a safe and effective natural skin moisturizer product.

Relation to Research Objectives and Implications

Overall, the findings of this study answer the three objectives formulated at the beginning: Chinese betel leaf extract is proven to maintain strong antioxidant activity after being formulated into a lotion preparation; the preparation shows good physical stability despite experiencing slight changes in viscosity and pH after the cycling test which are still within acceptable limits; and the preparation is proven to be statistically effective in increasing skin moisture without irritating. These findings strengthen the scientific basis for the use of Peperomia pellucida as an active ingredient in functional cosmetics based on local Indonesian natural resources, while opening up opportunities for further development, for example, formula optimization to lower the initial pH of the preparation closer to the physiological range of the skin from the start of production, as well as long-term stability studies under real storage conditions.

4. CONCLUSION

Based on the research results and discussions that have been described, several things can be concluded as follows. First, Chinese betel leaf extract (Peperomia pellucida) has a very strong antioxidant activity category with an IC50 value of 8.995 µg/mL, and after being formulated into lotion preparations at three concentration variations, its antioxidant activity remains relatively strong with IC50 values of 24.704 µg/mL (F1), 22.464 µg/mL (F2), and 21.231 µg/mL (F3), respectively, which shows a consistent dose-response relationship between extract concentration and free radical inhibition capacity. Second, the Chinese betel leaf extract lotion preparation showed good physical stability during the six-cycle cycling test, characterized by consistent homogeneity and oil-in-water (O/W) emulsion type in all formulas, despite a decrease in pH from the alkaline range (8.27–8.59) to near neutral (7.29–7.92) and an increase in viscosity due to repeated exposure to extreme temperatures, both of which were still within the acceptable physical quality limits of topical preparations. Third, the lotion preparation was proven to be effective in significantly increasing skin moisture ($p = 0.038$) during seven days of use, with the highest moisturizing effect in the highest extract concentration formula (F3), without causing irritation reactions in all test panelists, and obtaining good sensory acceptance, especially in formula F1.

Overall, this study proves that Chinese betel leaf extract can be formulated into a physically stable lotion preparation, has strong antioxidant activity, is safe to use, and effective as a skin moisturizer, so it has the potential to be further developed as a natural functional cosmetic. To improve the formula in further research, it is recommended to optimize the emulsifier system to lower the initial pH of the preparation to be closer to the physiological pH of the skin before storage, long-term stability testing at room temperature conditions to obtain a more accurate shelf life estimate, and extend the duration of the moisture test and irritation test to ensure the safety and effectiveness of the preparation in long-term use and on various skin types.

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