ISSN 2548-6462 (online), ISSN 2088-8740 (print)

DOI: 10.30644/rik.v15i1.1147

Lotion formulation from ethanol extract of Pedada leaves (*Sonneratia caseolaris*) as an antioxidant

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Accepted: 30 November 2025; revision: 12 January 2026; published: 31 January 2026

Abstract

Background: Pedada leaves contain bioactive compounds with antioxidant potential, yet their application in topical preparations remains limited. This study aimed to develop an antioxidant lotion and evaluate its physical quality, stability, antioxidant activity, user acceptance, safety, and skin brightening potential.
Method: This experimental study used extract obtained through maceration, followed by phytochemical screening, and DPPH antioxidant testing. Three formulations were prepared at different concentrations, along with K− (base lotion without extract) and K+ (commercial lotion). Physical evaluations included organoleptic characteristics, homogeneity, emulsion type, pH, viscosity, spreadability, adhesiveness, and stability. Antioxidant activity was determined using IC_{50} values. The best formulation was further assessed through hedonic testing, irritation testing, and skin brightening evaluation.
Results: The extract showed very strong antioxidant activity (IC_{50} = 27,44 ppm). All formulations produced stable, homogeneous emulsions. F3 demonstrated the strongest antioxidant activity (IC_{50} = 51,69 ppm). Hedonic tests indicated good acceptance, irritation occurred in only one respondent, and several participants showed a one level improvement in skin tone.
Conclusion: Pedada leaf extract exhibited antioxidant activity and was successfully incorporated into a lotion formulation. Based on physical evaluation, antioxidant activity, and sensory assessment, F3 was identified as the optimal formulation with performance comparable to the reference lotion.

Keywords: Pedada Leaves; Antioxidant; Lotion; DPPH.

INTRODUCTION

The skin is the primary protective layer of the body against external factors (1). However, despite functioning as a mechanical barrier, the skin is highly susceptible to oxidative stress, a condition characterized by increased levels of reactive oxygen species (ROS) that can disrupt cellular metabolism and regulation, leading to cellular damage due to an imbalance between free radicals and the antioxidant defense system (2). Direct exposure to sunlight without adequate protection is one of the main triggers of oxidative stress in the skin, which can result in premature aging, hyperpigmentation, and an increased risk of skin cancer (3).

Oxidative stress is closely associated with the presence of free radicals, which are atoms or molecules containing one or more unpaired electrons and are highly reactive. To achieve stability, free radicals react with surrounding molecules, initiating chain reactions that cause molecular abnormalities and tissue damage. Such damage contributes to various degenerative diseases, including cancer, cardiovascular disorders, premature aging, and other degenerative conditions. Therefore, effective protective mechanisms are required to reduce the detrimental effects of free radicals on the skin (4).

In this context, antioxidants play an important role as chemical compounds capable of donating one or more electrons to neutralize free radicals (5). Although the body is able to synthesize endogenous antioxidants such as superoxide dismutase, catalase, and glutathione peroxidase, excessive free radical production or reduced antioxidant capacity may lead to imbalance. Under these conditions, the intake of

exogenous antioxidants becomes necessary. Exogenous antioxidants can be obtained from natural bioactive sources that can be utilized by the body (4). Common synthetic antioxidants include butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), and tert-butylhydroquinone (TBHQ). However, long-term use of synthetic antioxidants may cause adverse effects, as they are considered potentially carcinogenic. Therefore, natural antioxidants which are widely available in nature, are highly needed. Natural antioxidants act systemically and can help prevent aging at both cellular and tissue levels. Plant derived natural antioxidants typically include phenolic or polyphenolic compounds (6).

One potential natural source of exogenous antioxidants is the pedada plant (Sonneratia caseolaris). This mangrove species contains phytochemical compounds closely associated with antioxidant activity, with secondary metabolite composition varying among plant parts and influenced by environmental conditions (7). Among these parts, the leaves are relatively underexplored. Pedada leaves have been reported to possess high antioxidant potential (8).

Along with the increasing demand for topical antioxidants for skin protection, lotion formulations have become one of the most commonly used dosage forms. Lotions are preparations in the form of solutions, suspensions, or emulsions intended for application to the skin (9). The advantages of lotions include high water content, good spreadability, ease of application, non-greasy texture, a cooling sensation, and ease of removal with water (10).

Previous studies support the potential use of pedada leaves, as ethanol extracts have been reported to contain bioactive compounds including alkaloids, flavonoids, saponins, polyphenols, tannins, and steroids. These compounds exhibit antioxidant activity through free-radical scavenging, evaluated via the DPPH method. The extract demonstrated strong antioxidant activity with an IC_{50} value of 14.196 ppm, higher than the fruit extract which had an IC_{50} of 24.590 ppm. These findings indicate that the leaves are a more potent antioxidant source compared to other plant parts (7). This result is consistent with earlier research reporting an IC_{50} value of 10.68 ppm, also categorized as very strong antioxidant activity (11). Collectively, these findings strengthen the justification for developing pedada leaves as an active ingredient in antioxidant based formulations.

Although the antioxidant activity of pedada leaves has been widely reported, studies investigating their development into lotion formulations remain limited. Most previous studies have focused primarily on antioxidant activity without comprehensively evaluating formulation aspects such as physical characteristics, stability, safety, user acceptability, and functional benefits for the skin. Therefore, the novelty of this study lies in the development and comprehensive evaluation of a lotion formulation containing pedada leaf extract as a functional antioxidant cosmetic product. This study aims to formulate a lotion containing pedada leaf extract and to evaluate its physical characteristics, storage stability, antioxidant activity, skin-brightening potential, safety, and user acceptability in order to obtain an optimal formulation in terms of quality and functionality.

METHOD

This study is an experimental research aimed at formulating a lotion preparation containing ethanol extract of pedada leaves and evaluating its physical quality and stability, antioxidant activity, user acceptance, safety through irritation testing, and skin brightening effect. The instruments used in this study included an analytical balance, oven, grinder, funnel, liquid thermometer, mortar, hotplate, pH meter, beaker glass, waterbath, volumetric flask, porcelain dish, test tubes, stirring rod, filter paper, viscometer, rotary evaporator, UV-Vis spectrophotometer, dropper pipette, glass slides, petri dishes, spatula, refrigerator, scaled ruler, sieve, lotion containers, adhesion testing device, and calibration weights. The materials used included pedada leaves (Sonneratia caseolaris), 70% ethanol, 2 N HCl, mayer's reagent, dragendorff's

reagent, concentrated HCl, magnesium powder, $AlCl_3$, $FeCl_3$, ethyl acetate, acetic anhydride, concentrated sulfuric acid, NaOH, liquid paraffin, butylene glycol, glycerin, glyceryl monostearate, polysorbate 60, cetyl alcohol, carbomer, triethanolamine, Na-EDTA, phenoxyethanol, essential oil, distilled water, ethanol p.a, and DPPH.

The pedada leaves used as raw material were collected from mangrove habitats and subsequently sorted, dried, ground, and sieved to obtain simplicia. Extraction was carried out using the maceration method for 3×24 hours with a solvent to simplicia ratio of 1:10, followed by remaceration for another 3×24 hours to increase yield. The resulting filtrate was first evaporated using a rotary evaporator to remove most of the solvent, and the final thickening process was performed using a waterbath to obtain a concentrated extract (12). The resulting extract was then analyzed for its moisture content and ash content, and subsequently subjected to phytochemical screening. Three extract concentrations were used in the formulation, namely F1 (0.1%), F2 (0.5%), and F3 (1%), along with K– as the lotion base without extract and K+ as the commercial lotion comparator. The lotion formulation was prepared based on the composition specified in the formulation table. The lotion formulation design was carried out using the components that had been arranged in the formulation table as follows:

Table 1. Formulation of Pedada Leaf Extract Antioxidant Lotion

Material	Concentration (%w/w)					Function
	F1	F2	F3	K-	K+	
Ekstrak etanol daun pedada	0,1	0,5	1,0	0,0		Natural antioxidant
Liquid paraffin	4,0	4,0	4,0	4,0		Emolient
Butylene glycol	2,5	2,5	2,5	2,5		Enhance spreading
Glycerin	4,5	4,5	4,5	4,5		Humectant
GMS	4,0	4,0	4,0	4,0		Emulsifier
Polysorbate 60	1,5	1,5	1,5	1,5	Commersial lotion brand "X" containing antioxidants	Co-emulsifier
Cetyl alcohol	2,0	2,0	2,0	2,0		Thickening agent
Carbomer	0,2	0,2	0,2	0,2		Thickening agent
TEA	0,1	0,1	0,1	0,1		Carbomer neutralizer
Na EDTA	0,2	0,2	0,2	0,2		Chelating agent
Phenoxyethanol	0,8	0,8	0,8	0,8		Preservative
Essential oil	0,2	0,2	0,2	0,2		Fragance
Aquadest	ad 100	ad 100	ad 100	ad 100		Solvent

The lotion was prepared by first heating the oil phase (liquid paraffin, GMS, and cetyl alcohol) and the water phase (distilled water, glycerin, polysorbate, and Na EDTA) separately to 70–75°C. Carbomer was dispersed in a portion of distilled water at room temperature and allowed to swell. After both phases reached the same temperature, the oil phase was poured into the water phase while stirring to form a stable emulsion. The mixture was cooled to 40–45°C, then the swollen carbomer gel was added, followed by TEA to neutralize it. Pedada leaf extract was added based on the formulation concentration. When the mixture cooled to 30–35°C, butylene glycol, phenoxyethanol, and essential oils were added. The lotion was stirred until homogeneous and allowed to stand until a uniform texture and aroma were achieved.

The physical quality evaluation of the lotion included tests for organoleptic properties, homogeneity, emulsion type, pH, viscosity, spreadability, adhesiveness, and stability. Stability was assessed using a six cycling test to observe changes in color,

aroma, appearance, pH, viscosity, spreadability, and adhesiveness (13). Antioxidant activity was measured using the DPPH method and expressed as IC_{50}. Skin brightening effectiveness was evaluated visually using a standardized human skin tone set, while safety was assessed through a closed patch irritation test on 30 healthy volunteers aged 18–35. Irritation parameters such as redness, itching, or swelling were observed after 24 hours. A hedonic test involving 30 semi-trained panelists was conducted to determine user acceptance based on attributes such as color, aroma, homogeneity, viscosity, smoothness, spreadability, absorption, softness, and stickiness using a 1–5 preference scale.

The experimental results included three replications, and the data were expressed as mean ± standard deviation (14). Data processing involved descriptive and statistical analyses to compare differences among the five formulations based on stability, homogeneity, organoleptic characteristics, pH, spreadability, adhesiveness, viscosity, and antioxidant activity. IC_{50} values were calculated using a linear regression equation (y = a + bx) derived from sample concentrations and absorbance readings. Normality and homogeneity were assessed using the Shapiro Wilk tests, respectively. If data were normally distributed and homogeneous, One Way ANOVA was used; otherwise, the Kruskal Wallis test was applied (15). Qualitative parameters such as stability, homogeneity, and organoleptic properties were analyzed descriptively through narrative and tabulation.

Statistical significance for the cycling test results was determined using the Paired Sample T-test, with the Wilcoxon test applied when normality assumptions were not met. Data were considered acceptable when the one tailed significance value was below 0,05 (16). Hedonic testing, irritation testing, and skin-brightening evaluation were performed only on the best formula identified from preliminary results and were analyzed descriptively. Hedonic data were presented as preference score distributions, irritation results were described narratively and in tables, and skin brightening outcomes were shown through comparisons of skin tone values before and after lotion application.

RESULTS

The research findings were obtained through a series of tests, including the characterization of the ethanolic extract of pedada leaves, evaluation of the physical quality and stability of the lotion formulations, assessment of antioxidant activity, and tests on acceptability, safety, and skin brightening effects. Each dataset was analyzed to determine the influence of the extract on the different lotion formulas and to evaluate the stability and performance of the formulations during storage. The following section presents the detailed results of these tests.

Table 2. Results of Extract Moisture Content and Ash Content

Parameter	Results (%)
Moisture content	11,1637
Ash content	23,0214

Table 3. Results of Phytochemical Screening of Ethanolic Pedada Leaf Extract

Classes of Compounds	Reagent	Results
Alkaloid	Dragendorff	+
	Mayer	+
Flavonoid	Wilstater	+
	sianidin	
	$AlCl_3$ 10%	+
Saponin	Hot distilled water	+
Tanin	$FeCl_3$ 1%	+
Steroid/ Terpenoid	Liebermen-burchard	-/+
Fenolik	$FeCl_3$ 1%	+
Kuinon	NaOH 2N	+

Table 4. Results of Antioxidant Activity of Extract

Sample	IC_{50} value (ppm)	Classification
Ethanol extract of pedada leaves	27,44179	Very strong

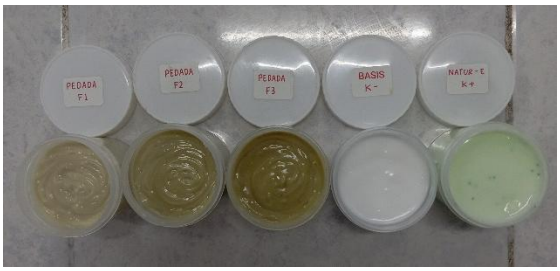

Figure 1. Lotion Preparations F1, F2, F3, K-, and K+

Table 5. Results of Organoleptic Evaluation

Formula	Shape	Color	Aroma
F1	Semi solid	Beige	Lavender fragrance
F2	Semi solid	Light moss green	Lavender fragrance
F3	Semi solid	Dark moss green	Lavender fragrance
K-	Semi solid	White	Lavender fragrance
K+	Semi solid	Light green	Cosmetic fragrance

Table 6. Results of Homogeneity Test

Formula	Results
F1	Homogen
F2	Homogen
F3	Homogen
K-	Homogen
K+	Homogen

Table 7. Results of Emulsion Type Test

Formula	Methylene Blue Test Result	Emulsion Type
F1	Dispersed uniformly	O/W
F2	Dispersed uniformly	O/W
F3	Dispersed uniformly	O/W
K-	Dispersed uniformly	O/W
K+	Dispersed uniformly	O/W

Table 8. Results of pH Test

Formula	Results (Mean ± SD)	
	Before the Cycling Test	After the Cycling Test
F1	7,43 ± 0,026	5,78 ± 0,030
F2	6,09 ± 0,036	a5,31 ± 0,01
F3	5,66 ± 0,035	5,46 ± 0,02
K-	5,96 ± 0,005	6,22 ± 0,01
K+	5,5 ± 0,02	5,72 ± 0,015

Table 9. Results of Viscosity Test

Formula	Results (Mean ± SD)	
	Before the Cycling Test	After the Cycling Test
F1	1995 ± 64,67	1094 ± 72,15
F2	1819 ± 128,3	1201 ± 97,32
F3	1126 ± 90,97	1158 ± 171,08
K-	2129 ± 204,2	1841 ± 418,45
K+	1430 ± 18,48	1446 ± 9,24

Table 10. Results of Spreadability Test

Formula	Results (Mean ± SD)	
	Before the Cycling Test	After the Cycling Test
F1	5,316 ± 0,058	5,162 ± 0,058
F2	5,45 ± 0,01	5,283 ± 0,014
F3	5,513 ± 0,025	5,439 ± 0,013
K-	5,243 ± 0,011	5,133 ± 0,132
K+	5,207 ± 0,023	5,117 ± 0,046

Table 11. Results of Adhesion Test

Formula	Results (Mean ± SD)	
	Before the Cycling Test	After the Cycling Test
F1	4,76 ± 0,017	4,69 ± 0,015
F2	4,66 ± 0,040	4,62 ± 0,02
F3	4,32 ± 0,036	4,28 ± 0,036
K-	4,97 ± 0,047	4,85 ± 0,02
K+	4,47 ± 0,026	4,37 ± 0,015

Table 12. Results of Antioxidant Activity of Formulations

Sample	IC_{50} value (ppm)	Classification
F1	65,16064	Strong
F2	53,76694	Strong
F3	51,6868	Strong
K-	97,75576	Strong
K+	42,11292	Very strong

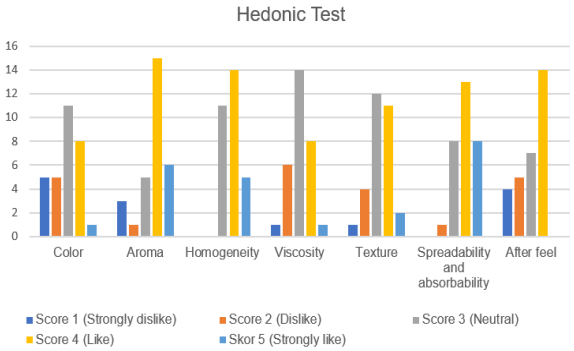

Figure 2. Hedonic Test Evaluation Chart

Table 13. Results of Irritation Test

Skin Response Category	Number of Respondents	Percentage (%)
No irritation	29	96,7
Mild irritation	1	3,3
Moderate irritation	0	0,0
Severe irritation	0	0,0
Total	**30**	**100**

Table 14. Results of Skin Brightening Test

Respondent code	Skin Color Scale	
	Before Application	After Application
R001	5	4
R002	6	5
R003	6	5
R004	5	5
R005	8	7
R006	6	6
R007	9	8
R008	7	6
R009	5	5
R010	9	9

DISCUSSION

The study began with the collection of samples from the mangrove area in Muara Sabak Barat District, Tanjung Jabung Timur Regency, Jambi Province. This location was selected based on the scientific assumption that plants growing in environmentally stressed areas, such as those exposed to fluctuating salinity and intense sunlight, may produce higher concentrations of secondary metabolites as a defense mechanism, which correlates directly with the antioxidant activity of interest. Plant determination was then conducted to ensure the authenticity of the sample, as species differences may influence chemical composition and biological activity. Determination results from the Plant Taxonomy Laboratory, Faculty of Mathematics and Natural Sciences, Padjadjaran University confirmed that the sample was pedada leaves, scientifically identified as Sonneratia caseolaris (L.) Engl., belonging to the family Lythraceae, a species well known for its high antioxidant potential.

The powdered pedada leaf simplicia was extracted after undergoing controlled drying at 60°C to reduce moisture content without damaging thermolabile compounds. The extraction process yielded a recovery value that met the required standards, exceeding the prescribed limit (17). The extract yield suggests that ethanol was effective in extracting polar and semipolar secondary metabolites from pedada leaves. The yield value reflects the amount of active compounds successfully extracted, the higher the yield, the greater the content of active constituents in the extract (18).

Moisture and ash content analyses were subsequently performed to assess extract quality. Moisture content reflects the amount of water that may influence stability and susceptibility to microbial growth, whereas ash content represents inorganic mineral content, indicating the presence of possible contaminants such as dust or soil (19). The results showed that the moisture content slightly exceeded the recommended limit, which could reduce stability and increase microbial risk. This high moisture content is influenced by the hygroscopic nature of the extract, rich in polar compounds, but it remains acceptable if stored in a dry environment and airtight containers (20). Meanwhile, the ash content was relatively high, possibly indicating the presence of mineral components or inorganic contaminants. This finding is consistent with the characteristics of mangrove plants, which

typically contain high mineral levels due to growth in saline coastal environments (21).

Further evaluation of extract quality involved phytochemical screening to identify groups of secondary metabolites present in the ethanolic extract of pedada leaves. This qualitative test detects bioactive compounds through chemical reactions with specific reagents, indicated by color changes, precipitate formation, or foam production (22). The presence of secondary metabolites suggests strong antioxidant potential, particularly as flavonoids and phenolic compounds play a key role in neutralizing free radicals through hydrogen atom donation. Tannins and quinones also contribute to antioxidant activity through polyphenolic mechanisms and free radical scavenging. Additionally, alkaloids and saponins can act as secondary antioxidants by indirectly suppressing free radicals, while terpenoids enhance antioxidant potential by stabilizing peroxyl radicals and protecting cell membranes from lipid oxidation. Overall, the phytochemical profile supports that paddle tree leaves contain bioactive compounds associated with high antioxidant activity.

Antioxidant activity testing of the ethanolic extract was conducted using the DPPH method. This method is widely used due to its simplicity, sensitivity, and ability to illustrate the hydrogen donating capacity of compounds in neutralizing free radicals. The results showed that the paddle tree leaf extract possessed very strong antioxidant activity. Therefore, the ethanolic extract of paddle tree leaves exhibits significant antioxidant potential, primarily attributed to secondary metabolites such as flavonoids, phenolics, and tannins, which act through proton or electron donation mechanisms (23).

After confirming that the ethanolic extract exhibited strong antioxidant activity and contained various secondary metabolites, lotion formulations were prepared to evaluate the stability and performance of the extract when applied topically. Physical evaluations were performed on each lotion variant, as it is essential to ensure that the addition of ethanolic extract at different concentrations not only provides biological benefits but also results in physically stable formulations.

Organoleptic tests were conducted to observe the color, aroma, and physical form of the lotions before and after the stability cycles as indicators of physical stability. The results showed that all formulations maintained a semi-solid form without consistency changes, indicating that the emulsions were stable under extreme temperature conditions. No changes in aroma were observed after the cycles, indicating that the scent remained stable and compatible with the lotion base. Lotion color was influenced by extract concentration, with higher concentrations resulting in a darker green color derived from chlorophyll and flavonoids. The absence of color changes after the cycles indicated that the active compounds in the extract remained stable without degradation or interactions affecting the product's appearance.

Homogeneity testing ensured that each lotion formula had an even composition without clumps, coarse particles, or color variation. Observations confirmed that all formulas were homogeneous both before and after cycling, indicating that the active and auxiliary ingredients were evenly dispersed and that the emulsion remained stable. Good homogeneity reflects optimal mixing and physical stability, ensuring consistent distribution of the active compound throughout the lotion (24).

The emulsion type was determined using methylene blue as an indicator to distinguish between oil in water (O/W) and water in oil (W/O) emulsions. All formulas exhibited evenly distributed blue coloration, confirming O/W emulsion types. This type is commonly preferred for lotions because it provides a lightweight, easily washable, non-greasy texture and comfortable application. The formation of O/W emulsions in all formulas indicates that the composition and emulsifier selection were appropriate, and the addition of extract did not disrupt emulsion stability.

pH testing was conducted to ensure the lotions were within the physiological pH range of the skin, making them safe and non-

irritating. The results showed a slight decrease in pH after the stability cycles, possibly due to degradation of components at high temperatures or changes in ionic balance during repeated heating and cooling. Nevertheless, all formulations remained within a safe range. Formula 3 showed a lower pH due to higher extract content, particularly tannins with acidic properties (8). Statistical analysis showed that before cycling, the data were not normally distributed, so the Kruskal Wallis test was used and indicated significant differences among formulas ($p = 0.009$), suggesting that extract concentration influenced lotion pH. After cycling, the data were normally distributed and homogeneous, allowing the use of One Way ANOVA, which also showed significant differences among formulas ($p < 0.05$). To assess changes in pH within each formula before and after cycling, the Wilcoxon Signed Rank Test was performed and showed no significant differences ($p > 0.05$). This indicates that although variations existed among formulas, the pH of each formula remained stable during storage.

Viscosity testing evaluated the lotion's thickness to ensure ease of application, adequate spreadability, and stability. Excessively low viscosity may limit active compound release, while excessively high viscosity may hinder spreading. Results showed that increasing extract concentration reduced viscosity, although the lotions still appeared thick visually. Factors such as solvent type, temperature, and mixing duration may also influence viscosity (25). All formulas exhibited viscosity values below the Indonesian National Standard (SNI), but were still acceptable, as the formulations remained physically stable and met other quality parameters. The commercial comparison lotion also exhibited low viscosity yet remained stable. After cycling, viscosity decreased across all formulas due to repeated temperature changes, but the reduction was minor and did not cause phase separation, indicating maintained physical stability. Statistical analysis using the Kruskal Wallis and Wilcoxon tests (due to non-normal data distribution) showed significant differences among formulas and between pre- and post-cycling values, indicating that temperature fluctuations affected viscosity.

Spreadability testing assessed the lotion's ability to spread on the skin, which influences user comfort, active distribution, and formulation effectiveness. All formulas met the standard, indicating good spreadability. Formulas containing pedada leaf extract (F1–F3) exhibited slightly higher spreadability compared to controls, as extract addition reduced viscosity, thereby improving spreading. After cycling, spreadability slightly decreased due to repeated heating and cooling, which may cause water evaporation and strengthen emulsion structure (26). However, spreadability values remained within acceptable limits. Statistical analysis using Kruskal Wallis and Wilcoxon tests showed significant differences among formulas and between pre and post cycling values, indicating that cycling affected spreadability, although the changes were relatively minor.

Adhesion testing evaluated how long the lotion adheres to the skin, which is important for maximizing active compound absorption. All formulas met the minimum standard, both before and after cycling, indicating that the formulations possessed adequate consistency and remained stable under extreme storage conditions. After cycling, adhesion slightly decreased due to viscosity reduction from temperature fluctuations. As viscosity is directly proportional to adhesion, decreased viscosity results in lower adhesion (27). Statistical analysis showed that before cycling, non-normal data required the Kruskal Wallis test, which indicated significant differences among formulas ($p < 0.05$). After cycling, normal and homogeneous data allowed the use of One Way ANOVA, which also showed significant differences. The Wilcoxon test showed significant differences between pre and post cycling values ($p < 0.05$), demonstrating that cycling influenced adhesion, although all values remained within the standard.

Stability testing was conducted to assess the lotion's ability to maintain physical quality after exposure to extreme

temperatures through the cycling test, representing long term stability without extended storage. The test was performed with temperature cycles of 4°C and 40°C for 24 hours each, repeated for six cycles, providing thermal stress to the emulsions. Observations showed that all formulas remained stable through the sixth cycle, with no changes in color, aroma, consistency, or phase separation, and all formulations remained homogeneous. This indicates that the emulsions had good physical stability, and the emulsifying agents successfully maintained emulsion structure despite extreme temperature fluctuations (28).

Antioxidant activity was then assessed on the lotions to evaluate the stability and efficacy of the extract after formulation. The results showed that the antioxidant activity of the lotions increased with increasing extract concentration, confirming that secondary metabolites directly contribute to the product's biological performance. Formula 3, with the highest extract concentration, exhibited superior antioxidant potential compared to other formulas, indicating that adjusting extract content allows for effective natural lotion formulations. The positive control (K+) showed very strong activity, primarily due to vitamin E (tocopherol), a lipophilic antioxidant capable of neutralizing free radicals by donating electrons or protons, while also protecting lipids in cell membranes and other sensitive molecules from oxidation. Meanwhile, the negative control (K−) still exhibited strong activity due to the mild reducing effect of ingredients such as glycerin and butylene glycol, which contain OH groups. Statistical analysis showed normally distributed but non-homogeneous data, so the Kruskal-Wallis test was used. A significance value of 0.009 ($p < 0.05$) indicated significant differences between formulas, confirming that extract concentration had a significant effect on lotion antioxidant activity.

Based on the results of physical characterization and antioxidant activity, Formula 3 (F3) was selected as the best formulation for further evaluation. This formula was chosen because it demonstrated optimal stability and superior performance across all quality parameters, with physical characteristics approaching those of the positive control (K+), a commercial lotion standardized by the cosmetics industry. The subsequent stages included sensory evaluation, skin irritation testing, and assessment of skin-brightening effects to comprehensively evaluate the lotion's safety, comfort, and effectiveness.

Hedonic testing showed that most panelists liked the lotion's aroma, homogeneity, spreadability, and smooth sensation after application, while color and viscosity received neutral to favorable ratings. These findings indicate that F3 was well accepted and comfortable to use. The safety of F3 on the skin was confirmed through irritation testing, which showed that the formulation was compatible with the skin and safe for use. Active compounds in the paddle tree leaf extract, including flavonoids and other bioactive compounds, can provide anti-inflammatory and antioxidant effects, helping to prevent redness or itching and supporting the recovery of mild skin reactions. Skin brightening tests over seven days showed an increase of approximately one shade in most respondents. This effect was due to active compounds in the paddle tree leaf extract neutralizing free radicals and inhibiting tyrosinase activity, thereby reducing melanin production and promoting brighter, more even skin (29). Although the brightening effect is slower than synthetic agents, routine use together with base ingredients such as glycerin and glyceryl monostearate, which maintain skin moisture, can support optimal results (30).

CONCLUSIONS

Based on the results of this study, pedada leaf extract (Sonneratia caseolaris) was successfully formulated into a stable oil in water (O/W) lotion. Among the tested formulations, Formula 3 demonstrated good physical stability, strong antioxidant activity, and clinical safety. The formulation was well-accepted by users and showed potential to enhance skin brightness. Overall, this lotion

represents an effective, safe, and user-friendly topical antioxidant preparation with potential benefits for skin health and appearance.

AKNOWLEDGEMENTS

The author expresses sincere gratitude to Jambi University, particularly the Faculty of Medicine and Health Sciences, for their support in providing research facilities and resources. Special thanks are extended to all volunteers who participated in the clinical evaluations, as their contributions were essential to this study. The author also wishes to acknowledge all others who directly or indirectly, played a role in supporting this research.

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