JURNAL RISET KEFARMASIAN INDONESIA
Ilmu Kefarmasian & Ilmu Kesehatan

Vol.8 Issue.1 (January 2026)
page 1-10
https://doi.org/10.33759/jrki.v8i1.909
e-ISSN: 2655-8289

Original Article

Determination of the *Sun Protection Factor* (SPF) of Ethanol Extract Gel from Arumanis Mango Leaves (*Mangifera indica L. var. arumanis*) as a Sunscreen Using the UV-Vis Spectrophotometry Method

Penentuan Nilai SPF (*Sun protection factor*) Ektrak Etanol Daun Mangga Arumanis (*Mangifera I. Var arumanis*) Sebagai Tabir Surya Menggunakan Metode Spektrometri UV Vis

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Submitted : 2025-12-09
Revised : 2026-01-15
Accepted : 2026-01-30

Keywords: Natural sunscreen, Mangifera indica, leaf extract, sun protection factor, topical gel, photoprotective agent

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Abstract

Skin damage caused by ultraviolet radiation has become a major health concern, prompting the search for natural photoprotective agents. This study aimed to determine the sun protection factor of ethanol-based *Mangifera indica* L. var. *arumanis* leaf extract and its topical gel formulations. Fresh mature leaves were dried, powdered, and extracted using maceration with 96% ethanol. The extract was subsequently formulated into gels with varying concentrations and evaluated for physical properties including pH, viscosity, spreadability, adhesion, homogeneity, and organoleptic characteristics. The sun protection factor was measured using UV-Visible spectrophotometry and calculated via the Mansur equation. Results showed that the ethanol extract provided ultra-level photoprotection at all tested concentrations, while gel formulations containing higher extract concentrations achieved enhanced sun protection, with optimal physical stability observed at intermediate concentrations. Excessive extract concentration resulted in reduced homogeneity and decreased adhesion. These findings demonstrate that *Mangifera indica* L. var. *arumanis* leaf extract is a promising natural sunscreen ingredient and that careful formulation is required to balance biological efficacy with physical stability. The study provides a basis for developing safe and effective natural sun protection products.

Abstrak

Kerusakan kulit akibat radiasi ultraviolet telah menjadi masalah kesehatan utama, sehingga mendorong pencarian agen fotoprotektif alami. Studi ini bertujuan untuk menentukan faktor perlindungan matahari (SPF) dari ekstrak daun *Mangifera indica* L. var. *arumanis* berbasis etanol dan formulasi gel topikalnya. Daun segar yang matang dikeringkan, dihaluskan, dan diekstrak menggunakan maserasi dengan etanol 96%. Ekstrak tersebut kemudian diformulasikan menjadi gel dengan berbagai konsentrasi dan dievaluasi sifat fisiknya termasuk pH, viskositas, daya sebar, adhesi, homogenitas, dan karakteristik organoleptik. Faktor perlindungan matahari diukur menggunakan spektrofotometri UV-Visible dan dihitung melalui persamaan Mansur. Hasil menunjukkan bahwa ekstrak etanol memberikan perlindungan fotoproteksi tingkat ultra pada semua konsentrasi yang diuji, sementara formulasi gel yang mengandung konsentrasi ekstrak yang lebih tinggi mencapai perlindungan matahari yang lebih baik, dengan stabilitas fisik optimal yang diamati pada konsentrasi menengah. Konsentrasi ekstrak yang berlebihan mengakibatkan penurunan homogenitas dan penurunan adhesi. Temuan ini menunjukkan bahwa *Mangifera indica* L. var. Ekstrak daun Arumanis merupakan bahan tabir surya alami yang menjanjikan dan diperlukan formulasi yang cermat untuk menyeimbangkan kemanjuran biologis dengan stabilitas fisik. Studi ini memberikan dasar untuk mengembangkan produk perlindungan matahari alami yang aman dan efektif.

How to Cite: (*citation style* AMA 11th Ed.)
Laikhah, Shaliha I. Determination of the sun protection factor (SPF) of ethanol extract gel from Arumanis mango leaves (*Mangifera indica* L. var. *arumanis*) as a sunscreen using the UV-Vis spectrophotometry method. *J Riset Kefarmasian Indones*. 2026;8(1):1-10. doi:10.33759/jrki.v8i1.909

INTRODUCTION

Skin cancer represents a major global health concern, with more than ten million new cases reported annually. In Indonesia, it ranks as the third most prevalent type of cancer after cervical and breast cancer, with a national prevalence estimated between 5.9% and 7.8% each year.[1] The high incidence of skin cancer in Indonesia is largely attributed to its geographical position within the tropical zone, where exposure to solar radiation is intense and continuous throughout the year. Among the components of solar radiation, ultraviolet (UV) radiation—particularly UV-A and UV-B—has been identified as the primary contributor to various forms of skin damage, including hyperpigmentation, photoaging, erythema, and carcinogenesis.[2]

Sunscreens are widely recognized as an essential preventive measure for reducing the adverse effects of UV radiation on human skin.[3] The effectiveness of sunscreen products is generally measured using the Sun Protection Factor (SPF), which indicates the capacity of a substance to absorb, reflect, or scatter UV radiation before it penetrates the skin.[4] In recent years, there has been increasing scientific and industrial interest in natural ingredients as photoprotective agents, motivated by concerns regarding the safety, environmental impact, and long-term effects of synthetic sunscreen compounds.[5]

Phenolic compounds, particularly flavonoids, have emerged as promising natural photoprotective agents due to their conjugated aromatic structures, which enable efficient absorption of UV radiation and provide antioxidant protection at the cellular level.[6] Mango leaves (*Mangifera indica* L.) contain high levels of flavonoids and have been traditionally used in various medicinal applications. Several previous studies have demonstrated that extracts of mango leaves possess photoprotective properties, with SPF values varying depending on the extraction method, solvent type, and concentration used.[7] These findings suggest that mango leaves hold potential as a natural sunscreen ingredient.

Given the need for safe, effective, and sustainable photoprotective compounds, further investigation into the SPF potential of mango leaf extracts is warranted. This study aims to determine the SPF value of ethanol-based mango leaf extract using UV-Vis spectrophotometry.[8] The results are expected to contribute to the development of natural sunscreen formulations and to provide scientific support for the utilization of *Mangifera indica* L. as a viable photoprotective agent.[9]

METHODS

This study employed several specialized instruments to ensure precise measurement and reproducibility. A UV-Visible Spectrophotometer (Shimadzu UV-1800, Japan) was used to measure the absorbance of extract solutions and gel formulations within the wavelength range of 290–320 nm.[10] An analytical balance (Ohaus Pioneer PA214, USA) with a precision of 0.0001 g was used for weighing samples.[11] A rotary vacuum evaporator (Heidolph Laborota 4000, Germany) facilitated solvent evaporation at 55°C during extract concentration.[12] Additionally, a digital pH meter (Hanna Instruments HI2211, USA) was used to determine gel pH, while a Brookfield viscometer (DV-E, USA) equipped with spindles no. 4–7 was used for viscosity analysis. Standard laboratory tools such as glassware and filtration equipment were also used but are not described in detail as they constitute routine laboratory equipment.[13]

The materials used in this study included analytical-grade ethanol 96%, ferric chloride ($FeCl_3$), hydrochloric acid, sulfuric acid, magnesium powder, and chloroform (all supplied by Merck, Germany).[14] Carbopol 940 and triethanolamine were sourced from Lubrizol and Sigma-Aldrich, respectively, while propylene glycol, methyl paraben,

and distilled water were obtained from Brataco Chemical, Indonesia. Plant material consisting of *Mangifera indica L. var. arumanis* leaves was collected from Singaraja Village, Indramayu District, Indonesia. Only mature green leaves approximately two months old (6–7 weeks) were selected. Authentication of the plant specimen was performed at the Laboratory of Mathematics and Natural Sciences, State Islamic University (UIN) Siber Syekh Nurjati Cirebon.

Tools and Materials

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Research Procedure

The research began with the preparation of plant simplisia. The fresh mango leaves were washed under running water, cut into smaller pieces, and dried under direct sunlight until completely dry.[15] The dried leaves were then ground into powder and sieved through a 40-mesh sieve to obtain uniform particle size.[16] Extraction was conducted using the maceration method by immersing 700 g of leaf powder in 3500 mL of 96% ethanol in a dark, tightly sealed container for three days at room temperature with intermittent stirring. The resulting extract was filtered using flannel cloth and Whatman filter paper, followed by concentration using a rotary evaporator at 55°C to yield a viscous ethanol extract.[17] Extract yield was calculated based on the ratio of final extract weight to the initial weight of the simplisia.

Phytochemical screening of the extract was carried out to detect the presence of alkaloids, flavonoids, tannins, saponins, and terpenoids using standard qualitative assays.[18] Positive results were indicated by characteristic color changes or precipitate formation, confirming the presence of secondary metabolites relevant to photoprotective activity.

The ethanol extract was subsequently formulated into a topical gel. Four formulations were prepared using different concentrations of mango leaf extract (0 g, 2 g, 4 g, and 6 g). Carbopol 940 was dispersed in hot water and neutralized with triethanolamine to form the gel base. Methyl paraben solution and propylene glycol were incorporated as preservatives and humectants, respectively. The appropriate amount of mango leaf extract was added to the gel base, and the mixture was homogenized to produce a uniform gel formulation.[19]

Each gel formulation underwent several evaluations. Organoleptic assessment was conducted to examine color, odor, and texture. pH was measured using a calibrated digital pH meter to ensure compatibility with the skin's

natural pH range. Viscosity was determined using a Brookfield viscometer.[20] Spreadability testing was conducted by placing the gel between two glass plates under varying loads and measuring the resulting spread diameter. Adhesion was assessed by measuring the time required for two glass slides adhered by the gel to detach. Homogeneity was examined by visually inspecting the gel on a glass slide for the absence of coarse particles.

Determination of SPF values was conducted using the Mansur equation. Extract solutions at concentrations of 2500 ppm, 3750 ppm, and 5000 ppm were prepared in ethanol, while gel samples were diluted to 50,000 ppm. Absorbance readings were taken at 5 nm intervals from 290 to 320 nm.[21] Ethanol served as the blank. SPF values were calculated using established erythemal effect (EE) and solar intensity (I) coefficients for each wavelength.

Ethical approval was not required for this study, as no human or animal subjects were involved.

Data Analysis

Data were analyzed using a quantitative descriptive approach. Absorbance values obtained from the UV-Vis spectrophotometer were processed using Microsoft Excel to calculate SPF values based on the Mansur equation. The equation incorporates a correction factor (CF = 10), wavelength-specific erythemal effect values, solar intensity coefficients, and the measured absorbance at each wavelength. The resulting SPF values were used to evaluate and compare the photoprotective potential of the ethanol extract and gel formulations of *Mangifera indica L. var. arumanis*. The analysis focused on identifying trends related to extract concentration and its effect on the SPF value of the gel.

RESULT AND DISCUSSION

Result

Plant Identification

Accurate botanical identification is essential to ensure the validity and reproducibility of natural product research. Determination conducted at the Laboratory of Mathematics and Natural Sciences, UIN Siber Syekh Nurjati Cirebon confirmed that the plant material used in this study belonged to *Mangifera indica L. var. arumanis*, family Anacardiaceae. This confirmation is crucial because phytochemical profiles differ significantly among mango varieties, and such differences can influence the yield and biological activity of the extract. The arumanis cultivar is well known for its high flavonoid and phenolic content, supporting its potential as a strong natural photoprotective agent.

Preparation of Simplisia and Extract Yield

The preparation of plant simplicia involved washing, drying under controlled sunlight exposure, pulverizing, and sieving to obtain a fine, uniform powder suitable for extraction. The extraction process was carried out using maceration with 96% ethanol, producing the following extract yield.

Table 1. Yield of *Mangifera indica Arumanis Leaf* Extract

Extract Type	Weight of Simplisia (gram)	Weight of Extract (gram)	% Yield
Thick extract	300	67.53	19.176

A yield of 19.176% is considered high for leaf-based extraction and indicates that the plant material contains substantial amounts of semi-polar bioactive compounds.[22] Ethanol 96%, a semi-polar solvent, effectively extracted flavonoids, tannins, and certain terpenoids without degrading thermolabile constituents. The high yield reflects not only the chemical richness of arumanis leaves but also the suitability of maceration for preserving secondary metabolites.

Phytochemical Screening

Phytochemical analysis was performed to identify secondary metabolites responsible for biological and photoprotective activity.

Table 2. Phytochemical Screening Results

No	Compound Group	Reagent	Color Change	Result
1	Saponins	Foam test	Stable foam	+
2	Flavonoids	Mg + HCl	Orange–yellow	+
3	Tannins	$FeCl_3$ 1%	Dark green–blue	+
4	Terpenoids	Chloroform + H_2SO_4	Reddish-brown	+
5	Alkaloids	Dragendorff/Mayer	Orange or whitish precipitate	+

The positive detection of flavonoids and tannins is particularly relevant to photoprotective function. Flavonoids possess conjugated aromatic chromophores capable of absorbing UV radiation and dissipating its energy safely, while tannins display potent antioxidant activity that neutralizes UV-induced free radicals.[23] The presence of terpenoids and alkaloids adds additional pharmacological value, as these compounds commonly exhibit anti-inflammatory and antimicrobial activities. This phytochemical profile strongly supports the potential of arumanis mango leaves as a natural source of sunscreen agents.

Organoleptic Evaluation

Organoleptic assessment revealed differences in physical characteristics among the gel formulations.

Table 3. Organoleptic Evaluation

Formulation	Color	Form	Odor
F0	White	Gel	Odorless
F1	Light brown	Gel	Mild mango-leaf odor
F2	Dark brown	Gel	Strong mango-leaf odor
F3	Greenish brown	Dense gel	Most intense odor

Increasing extract concentration resulted in progressively darker coloration and stronger odor due to the higher phytochemical load. F3, containing the highest concentration, exhibited a dense texture and deep color, indicating strong interactions between extract constituents and the gel base.[24] These properties illustrate the direct influence of extract concentration on sensory characteristics, which are important for consumer acceptance.

Viscosity Evaluation

Viscosity reflects the structural integrity and stability of gel formulations.

Table 4. Viscosity Test Results

Formulation	Spindle	Speed (rpm)	Concentration (%)	Viscosity (cP)
F0	07	50	44.0	35,200
F1	06	3.0	13.2	44,000
F2	04	1.0	23.8	47,800
F3	07	50	43.8	35,040

All formulations fall within the acceptable viscosity range for topical gels (2,000–50,000 cP). F2 had the highest viscosity, suggesting optimal interaction between the gel matrix and extract, resulting in a stable gel network.[25] Interestingly, F3 displayed lower viscosity than expected despite a high extract concentration, which aligns with later findings on poor homogeneity. This reduction in viscosity indicates incomplete dispersion of extract components, preventing the formation of a cohesive gel structure.

pH Evaluation

The pH of topical preparations must be compatible with the skin's physiological pH.

Table 5. pH Test Results

Formulation	Repl. 1	Repl. 2	Repl. 3	Final
F0	4.28	4.44	4.17	4.44
F1	4.46	4.51	4.43	4.51
F2	5.17	4.89	4.99	4.89
F3	6.94	6.97	7.00	6.97

F1 and F2 fall within the ideal skin pH range (4.5–6.5).[26] F0 is slightly more acidic, while F3 exceeds the upper limit, likely due to excess triethanolamine during neutralization of carbopol. Maintaining pH within the physiological range is critical to minimize irritation and ensure compatibility with the skin barrier.

Spreadability Evaluation

Spreadability is essential for ensuring even distribution of sunscreen on the skin surface.

Table 6. Spreadability Test Results

Formulation	50 g	100 g	150 g	Mean
F0	3.4	4.0	4.09	4.0
F1	4.4	5.3	5.8	5.3
F2	5.3	5.9	6.3	5.9
F3	3.5	4.8	4.9	4.8

F2 meets the optimal spreadability range (5–7 cm), demonstrating a gel that is both easily applicable and sufficiently fluid.[27] F0 and F3 exhibited lower spreadability due to higher viscosity and structural rigidity, with F3 further hindered by particulate non-uniformity.

Homogeneity Evaluation

Table 7. Homogeneity Test Results

Formulation	Result
F0	Homogeneous
F1	Homogeneous
F2	Homogeneous
F3	Not homogeneous

Only F3 failed the homogeneity test, presenting visible particles and uneven distribution of extract.[28] This confirms that excessively high concentrations of extract exceed the dispersion capacity of the gel base, affecting both appearance and performance.

Adhesion Evaluation

Table 8. Adhesion Test Results

Formulation	R1	R2	R3	Final
F0	2.04	2.85	2.28	2.28
F1	2.26	1.45	1.71	1.71
F2	1.63	1.33	1.35	1.35
F3	0.78	0.97	1.39	0.97

F1 and F2 demonstrated ideal adhesion values (1–5 seconds), ensuring adequate contact time with the skin.[29] F3, however, exhibited poor adhesion, likely due to structural inconsistency and lack of homogeneity, which impeded its ability to form a uniform adhesive film.

SPF Value of Extract

Table 9. SPF Values of Ethanol Extract

Concentration (ppm)	SPF Value	Category
2500	62.447	Ultra
3750	61.083	Ultra
5000	61.783	Ultra

All extract concentrations yielded ultra-level photoprotection. Interestingly, SPF values did not increase proportionally with concentration.[30] This may be attributed to optical saturation or overlapping UV absorption among densely concentrated flavonoids, resulting in diminished efficiency at higher concentrations.

SPF Value of Gel Formulations

Table 10. SPF Values of Gel Formulations

Formulation	SPF Value	Category
F0	1.494	Minimal protection
F1	14.318	Maximum protection
F2	31.693	Ultra protection
F3	32.604	Ultra protection

SPF values significantly increased with extract concentration.[27] F2 and F3 demonstrated ultra protection, confirming the strong photoprotective activity of arumanis mango leaf extract. However, despite high SPF, the physical instability of F3 highlights the importance of balancing biological activity with formulation quality.

Discussion

The study demonstrated that *Mangifera indica* L. var. *arumanis* leaf extract possesses significant photoprotective potential, confirmed by the high SPF values observed in both the ethanol extract and the gel formulations. The SPF values calculated for the ethanol extract at concentrations of 2500 ppm, 3750 ppm, and 5000 ppm indicated ultra-level protection, which aligns with previous studies that have shown the effectiveness of mango

leaves in providing UV protection. The flavonoids, tannins, and terpenoids detected in the extract are known to contribute to its ability to absorb UV radiation and neutralize free radicals, reinforcing the extract's potential as a natural sunscreen agent.

The gel formulations, particularly F2 and F3, exhibited ultra-level protection with SPF values of 31.693 and 32.604, respectively, despite F3 showing physical instability. This result highlights the importance of formulation quality in enhancing the photoprotective activity of the extract. Formulations with higher extract concentrations showed stronger photoprotection, but the challenges of homogeneity and adhesion at the highest concentration (F3) underline the need for careful formulation optimization. The findings also suggest that while higher extract concentrations may improve SPF, they can also compromise the gel's sensory properties and overall stability.

The organoleptic properties of the gels varied with the concentration of the extract. As expected, the higher the extract concentration, the darker the color and stronger the odor, which corresponds to the increased phytochemical load. These characteristics are crucial for consumer acceptance, as products with strong scents or unattractive colors may have reduced market appeal. In terms of physical stability, the F2 formulation with a medium extract concentration demonstrated the best balance between photoprotective efficacy and product stability.

Viscosity testing showed that all formulations were within the acceptable range for topical gels. However, the formulation with the highest extract concentration (F3) exhibited lower viscosity than expected, which was attributed to poor homogeneity. This suggests that high concentrations of extract may affect the gel's ability to form a uniform structure, potentially compromising its stability and efficacy.

Furthermore, the pH values of the formulations indicated that F1 and F2 were within the ideal range for skin compatibility (4.5–6.5). This is essential, as formulations with inappropriate pH levels could lead to skin irritation, reducing their dermatological safety. The adhesion testing also showed that F1 and F2 had ideal adhesion values, ensuring that the gel remains in contact with the skin long enough to provide effective protection.

While the findings demonstrate the potential of *Mangifera indica* L. var. *arumanis* leaf extract as a natural sunscreen agent, the study has several limitations. The in vitro SPF testing used the Mansur equation, which measures UV absorbance but does not fully replicate the biological responses of human skin. Long-term stability and dermatological safety were not assessed, and the gel's performance under actual usage conditions remains uncertain. Future studies should address these limitations by incorporating in vivo evaluations, conducting stability studies, and testing for skin irritation. Additionally, exploring different extraction methods and solvents may provide further insight into optimizing the photoprotective properties of mango leaf extracts

Limitation

This study presents several limitations that should be considered when interpreting the findings. The SPF values reported were obtained using the Mansur in vitro method, which relies solely on UV absorbance measurements and may not fully represent the biological responses of human skin under real-use conditions. Long-term stability testing of the gel formulations was not conducted, leaving potential changes in viscosity, color, pH, odor, and overall physical integrity during storage unexamined. The study also did not include skin irritation or safety testing; therefore, the dermatological compatibility of the formulations cannot yet be confirmed. Furthermore, the lack of homogeneity observed in the highest extract concentration (F3) indicates limitations in the gel matrix's capacity to incorporate high phytochemical loads, which may affect both performance and user acceptability. The study employed only one extraction method, one solvent, and a single plant variety, which restricts the

generalizability of the results across different extraction techniques or other cultivars of *Mangifera indica* L. Future research is recommended to include in vivo evaluations, accelerated stability studies, formulation optimization based on rheological behavior, comparative extraction approaches, and comprehensive safety assessments to obtain a more complete understanding of the photoprotective potential of arumanis mango leaf extract.

CONCLUSION

The study demonstrates that ethanol-based extracts of *Mangifera indica* L. var. *arumanis* exhibit significant photoprotective activity, with ultra-level SPF values achieved in both extract solutions and topical gel formulations. The results indicate that flavonoids, tannins, and other secondary metabolites present in arumanis leaves contribute effectively to UV absorption and antioxidant protection, highlighting the potential of this natural ingredient as a safe and sustainable alternative to synthetic sunscreens. While higher concentrations improve photoprotective efficacy, formulation stability and homogeneity must be carefully balanced to ensure optimal product performance and user acceptability. These findings provide a scientific foundation for the development of natural sunscreen products and suggest further exploration into in vivo testing, long-term stability, and formulation optimization to maximize the practical application of arumanis mango leaf extract in dermatological and cosmetic products.

FUNDING

This research received no external funding.

ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to the Mathematics and Natural Sciences Laboratory at UIN Syekh Nurjati Cirebon for the facilities and technical support provided, which made this research possible. Special thanks are directed to the laboratory staff who assisted in the preparation of plant materials and the implementation of laboratory analysis. The authors also appreciate the valuable input and suggestions from colleagues during the initial presentation of this research, which greatly contributed to improving the quality of the study. Finally, the authors extend their thanks to the local community in Singaraja Village, Indramayu District, for their cooperation in providing the plant materials used in this research.

AUTHOR CONTRIBUTION STATEMENT

LAIKHAH: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing—Original Draft Preparation, Writing—Reviewing and Editing, Visualization, Supervision, Validation.

CONFLICT OF INTEREST DECLARATION

The author declares no conflict of interest.

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