Development of Sun Screen Gel Formulation from Secang Wood Extract (Caesalpinia sappan L.)

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Exposure to ultraviolet (UV) radiation can cause oxidative stress, premature aging, and even skin cancer, so it is necessary to develop sunscreens based on natural ingredients that are safe and effective. Secang wood (Caesalpinia sappan L.) is known to contain phenolic compounds and brazilin which have antioxidant activity and have the potential as photoprotective agents. This study aims to develop a sunscreen gel formulation from ethanol extract of secang wood and evaluate its antioxidant activity, Sun Protection Factor (SPF) value, physical characteristics, and stability. Extraction was carried out using the maceration method using 96% ethanol. Antioxidant activity was determined using the DPPH method, while sunscreen activity was analyzed in vitro using UV-Vis spectrophotometry with the Mansur method. The gel was formulated in four formulas with varying extract concentrations (0.85% and 1.7%) and Carbopol (0.75% and 1%). Evaluation of the preparation included organoleptic tests, homogeneity, pH, viscosity, syneresis, spreadability, adhesion, and accelerated stability. The results showed that the ethanol extract of sappanwood has strong antioxidant activity with an IC50 value of 58.503 µg/mL. The SPF values of the extract at concentrations of 500, 850, and 1000 ppm were 49.59; 46.64; and 45.86, respectively, which are included in the high protection category. The SPF value of the gel preparation ranged from 15.11 to 22.36, with formula F2 (0.85% extract and 1% Carbopol) producing the highest SPF value of 22.355 ± 0.085. All formulas met the physical quality requirements of topical preparations with a pH range of 4.59-4.91, viscosity of 122.8-283.7 P, spreadability of 4.40-5.38 cm, and adhesiveness of 4.3-4.6 seconds. The results of the study indicate that the ethanol extract of sappanwood has the potential to be developed as an active ingredient in natural sunscreen in the form of a stable, safe, and effective gel preparation.
Keywords: *Caesalpinia sappan*L., sappan wood, antioxidant, sunscreen gel, SPF, Carbopol.

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1. Introduction

Exposure to ultraviolet (UV) radiation is one of the main environmental factors contributing to skin damage. UV rays, particularly UV-A (320-400 nm) and UV-B (290-320 nm), can trigger the formation of reactive oxygen species (ROS), which cause oxidative stress, lipid peroxidation, DNA damage, inflammation, hyperpigmentation, premature aging, and an increased risk of skin cancer (Al-Sadek & Yusuf, 2024). Increasing sun exposure due to global climate change and outdoor activities has led to a growing need for skin protection products (Haykal et al., 2025).

The use of sunscreen is an effective preventive strategy to protect the skin from the harmful effects of ultraviolet radiation. The effectiveness of a sunscreen is generally expressed through its Sun Protection Factor (SPF), which describes the product's ability to reduce the effects of erythema caused by UV exposure (Henderson et al., 2022). Conventional sunscreen products generally use synthetic active ingredients such as oxybenzone, octinoxate, avobenzone, and octocrylene. However, long-term use of synthetic ingredients has been reported to cause various side effects, such as skin irritation, allergic reactions, endocrine disruption, and potentially negative impacts on the aquatic environment (Alnuqaydan, 2024).

In recent years, research into the use of natural ingredients as photoprotective agents has experienced rapid development. Bioactive compounds derived from plants are known to have high antioxidant activity, thus being able to ward off free radicals formed due to exposure to ultraviolet light (Budzianowska et al., 2025). Furthermore, natural ingredients tend to be safer, more biocompatible, and more acceptable to consumers, as the trend towards the use of herbal and natural cosmetic products increases. One plant that has great potential to be developed as an active ingredient in natural sunscreens is sappan wood (Caesalpinia sappan L.) (Vij et al., 2023). This plant has long been used in traditional medicine because it contains various efficacious secondary metabolites, including brazilin, brazilein, flavonoids, phenolics, tannins, and saponins. Brazilin is the main component of sappan wood, which is known to have antioxidant, anti-inflammatory, antimicrobial, and protective activity against cell damage caused by oxidative stress (Insuan et al., 2024).

Antioxidant activity is closely related to a substance's ability to provide protection against ultraviolet radiation exposure (Solano, 2020). Antioxidants work by neutralizing free radicals, thereby inhibiting biomolecular damage to skin tissue (Michalak, 2022). Several studies have reported that sappanwood extract has high antioxidant capacity and has the potential to be used as an active ingredient in functional cosmetics, including sunscreen preparations. In this study, the ethanol extract of sappanwood showed strong antioxidant activity with an IC50 value of 58.503 μg/mL. Based on the classification of antioxidant activity, this value is categorized as a strong antioxidant, indicating the presence of bioactive compounds that have the potential to provide photoprotective effects (Bouteche et al., 2024).

In addition to its antioxidant activity, the ability of sappanwood extract to absorb ultraviolet radiation is also an important parameter in the development of sunscreen preparations (Tarumiyo et al., 2025). The results of measuring the SPF value of sappanwood ethanol extract showed a range of values between 45.85-49.59 at a concentration of 500-1000 ppm. This value is categorized as high protection and indicates that sappanwood extract has good ability to inhibit UV light penetration to the skin surface (Shi et al., 2025). These findings strengthen the potential of sappanwood as a source of natural sunscreen active ingredients that can be further developed in the form of topical pharmaceutical preparations (Wirawati et al., 2023).

Gel preparations are chosen as topical delivery systems because they offer several advantages over other dosage forms, including a cooling sensation on the skin, ease of application, non-stickiness, ease of washing off with water, and good release of active ingredients (Barnes et al., 2021). These characteristics make gels a suitable dosage form for modern sunscreen products. However, the success of gel formulations is greatly influenced by the type and concentration of the gelling agent used (Abdeltawab et al., 2020).

Carbopol is a synthetic gelling agent widely used in gel formulations because it produces high viscosity at low concentrations, has good physical stability, is compatible with various active ingredients, and produces a clear gel appearance (Pahlevi et al., 2026). Variations in carbopol concentration are known to affect the physical characteristics of the preparation, including homogeneity, pH, viscosity, spreadability, adhesion, syneresis, and storage stability. Furthermore, changes in the physical properties of the preparation can also impact the effectiveness of photoprotection, as indicated by the SPF value (Infante et al., 2021).

Several previous studies have reported the antioxidant activity and photoprotective potential of sappanwood extract, however, studies on sunscreen gel formulations based on sappanwood extract with varying Carbopol concentrations and evaluation of its physical stability are still relatively limited (Luo et al., 2025). Therefore, this study was conducted to develop a sunscreen gel formulation from ethanol extract of sappanwood (Caesalpinia sappan L.) using Carbopol as a gelling agent at different concentrations and to evaluate the physical characteristics, stability of the preparation, and effectiveness of protection against ultraviolet radiation through in vitro determination of SPF values (Saryanti et al., 2022). The results of this study are expected to provide scientific contributions in the development of herbal cosmetic products based on natural ingredients that are safe, effective, and have added value as an alternative to synthetic sunscreens.

2. Literature Review and Problem Statement

Ultraviolet Radiation and the Need for Sunscreen Development

Exposure to ultraviolet (UV) radiation, particularly UV-A and UV-B, is a major cause of skin damage. Continuous exposure can increase the formation of Reactive Oxygen Species (ROS), triggering oxidative stress, DNA damage, lipid peroxidation, inflammation, hyperpigmentation, premature aging, and increasing the risk of skin cancer. This condition is exacerbated by increased sunlight intensity due to climate change and increased outdoor activity. Therefore, the use of sunscreen is an effective preventive measure to protect the skin from the negative effects of UV radiation. Sunscreen effectiveness is generally measured by the Sun Protection Factor (SPF) value, which indicates a product's ability to reduce the effects of erythema caused by ultraviolet light exposure. Although synthetic sunscreens have been widely used, various studies have reported that some synthetic active ingredients have the potential to cause irritation, allergies, endocrine disruption, and have negative impacts on the environment, thus encouraging the development of sunscreens based on natural ingredients that are safer and more environmentally friendly.

Potential of Secang Wood Extract (Caesalpinia sappan L.) as an Active Ingredient in Sunscreen

Sappan wood (Caesalpinia sappan L.) is a medicinal plant that has great potential as a source of active ingredients in natural sunscreens because it is rich in secondary metabolites, such as brazilin, brazilein, flavonoids, phenolics, tannins, and saponins. These compounds are known to have high antioxidant activity, thus neutralizing free radicals formed due to exposure to ultraviolet light. This antioxidant activity plays an important role in preventing biomolecular damage to skin tissue and supporting photoprotection mechanisms. Various studies have shown that ethanol extract of sappan wood has strong antioxidant activity with an IC_{50} value that is included in the strong antioxidant category, and has an SPF value that is in the high protection category. These findings indicate that sappan wood extract not only functions as an antioxidant but also has the ability to absorb ultraviolet radiation, so it has the potential to be developed as an active ingredient in cosmetic and topical pharmaceutical preparations.

Gel Formulation as a Sunscreen Delivery System

Gel is a topical dosage form often chosen in sunscreen formulations due to its various advantages, such as providing a cooling sensation upon application, being easy to spread evenly on the skin surface, being non-sticky, being easy to clean with water, and being able to optimally release active ingredients. These characteristics increase comfort of use and thus have the potential to increase consumer compliance in using sunscreen. The success of gel formulations is greatly influenced by the choice of gelling agent, as this material determines the physical properties, stability, and release ability of the active ingredient from the preparation. Therefore, selecting the right delivery system is a crucial aspect in the development of natural-based sunscreen products to achieve effectiveness and good quality.

The Role of Carbopol in the Development of Sunscreen Gel

Carbopol is a synthetic gelling agent widely used in gel formulations because it produces high viscosity at low concentrations, provides a clear gel appearance, has good physical stability, and is compatible with various active ingredients. Variations in Carbopol concentration are known to affect the physical characteristics of the gel, such as pH, homogeneity, viscosity, spreadability, adhesion, syneresis, and stability during storage. Changes in these physical characteristics can also affect the release of active substances and the effectiveness of photoprotection as indicated by the SPF value. Although research on the antioxidant activity and photoprotective ability of sappanwood extract has been widely conducted, studies on the formulation of sunscreen gels from sappanwood extract with varying Carbopol concentrations and evaluation of physical characteristics, stability, and SPF effectiveness are still limited. Therefore, research on the development of sunscreen gel formulations from sappanwood extract using varying Carbopol concentrations is important to produce stable, effective preparations that meet pharmaceutical quality requirements.

Problem Statement

The Problem of Ultraviolet Radiation Exposure to Skin Health

Increasing exposure to ultraviolet light due to climate change and increased outdoor activity has led to a growing risk of skin damage. Using sunscreen is essential for skin protection, but commercially available products are still dominated by synthetic active ingredients that have the potential to cause side effects for both health and the environment. This situation highlights the need to develop safer, more natural alternatives to sunscreen.

The Potential of Secang Wood that Has Not Been Optimally Utilized

Sappan wood extract is known to contain high levels of antioxidant compounds and photoprotective properties, making it a potential active ingredient in natural sunscreens. However, most research has focused on testing the extract's antioxidant activity and SPF value, while development into a ready-to-use topical pharmaceutical product is still relatively limited. Therefore, research is needed to develop more applicable forms of sappanwood extract.

The Effect of Carbopol Concentration on the Quality of Sunscreen Gel

The success of a gel formulation is greatly influenced by the concentration of the gelling agent used. Variations in Carbopol concentration can affect the physical characteristics of the preparation, such as viscosity, pH, homogeneity, spreadability, adhesion, and storage stability. These changes in physical properties also have the potential to affect the release of active ingredients and the effectiveness of protection against ultraviolet light. Therefore, a formulation with an optimum Carbopol concentration is necessary to obtain a gel preparation that meets quality requirements.

Research Gaps and Urgency of Formulation Development

Until now, there are still few studies that comprehensively examine the development of sunscreen gel formulations from sappan wood extract with varying Carbopol concentrations accompanied by evaluation of physical characteristics, stability, and SPF values in vitro. This research gap is the basis for conducting the study "Development of Sunscreen Gel Formulations from Secang Wood Extract (Caesalpinia sappan L.)" to produce a stable gel formulation, effectively providing protection against ultraviolet radiation, and has the potential to be an alternative herbal sunscreen product that is safe and economical.

3. Method

This research is an experimental study with a quantitative approach aimed at developing a sunscreen gel formulation containing the active ingredient of ethanol extract of sappan wood (Caesalpinia sappan L.) and evaluating its antioxidant activity, Sun Protection Factor (SPF) value, and physical characteristics. The study was conducted at the Pharmaceutical and Natural Products Laboratory of the Muslim University of Indonesia, Makassar, from August to December 2025.

The sappanwood samples were obtained from Bone Regency, South Sulawesi. The raw material was cut into small pieces, shaved, dried, and then extracted using a maceration method with 96% ethanol. A total of 200 g of sappanwood powder was macerated using 2.5 L of ethanol for 72 hours with periodic stirring. The filtrate was filtered and then evaporated using a rotary evaporator at 60°C and 60 rpm until a thick extract was obtained.

The antioxidant activity of the extract was determined using the DPPH method. A 50 ppm DPPH solution was prepared in absolute methanol, while the extract solutions were prepared at various concentrations.(Mensor et al., 2001). A total of 0.5 mL of sample solution was mixed with 3.5 mL of DPPH, incubated for 30 minutes in the dark, then the absorbance was measured using a UV-Vis spectrophotometer at a wavelength of 516 nm. Quercetin was used as a positive control.(kumar et al., 2026).

The sunscreen gel is formulated in four formulas with varying concentrations of sappanwood extract (0.85% and 1.7%) and Carbopol as a gelling agent (0.75% and 1%). The formulas also contain triethanolamine, sodium benzoate, glycerin, propylene glycol, and distilled water. The gel is made by dispersing Carbopol in distilled water, followed by the addition of triethanolamine, additional ingredients, and extracts until a homogeneous preparation is obtained.(Eryani et al., 2025)Accelerated stability testing was conducted using the freeze-thaw cycling method for five cycles, each at 5°C and 35°C for 12 hours. Physical quality evaluation included organoleptic, homogeneity, pH, viscosity, rheology, spreadability, adhesiveness, and syneresis.(Hafifah et al., 2025).

Sunscreen activity was determined in vitro using UV-Vis spectrophotometry at a wavelength range of 290-320 nm with 5 nm intervals. The SPF values of the extracts and gel preparations were calculated using the Mansur equation based on the absorbance data obtained. All tests were conducted in triplicate, and data were analyzed descriptively and using ANOVA to determine the effect of treatment on the characteristics of the preparations.(Ansarian et al., 2022).

4. Results and Discussion

Result

Antioxidant Activity of Secang Wood Extract

Table 1. Antioxidant activity of ethanol extract of sappan wood (Caesalpinia sappan L.)

Concentration (ppm)	Sample Absorbance	% Inhibition
20	0.611	23.63
40	0.506	36.75
60	0.390	51.25
80	0.308	61.50
100	0.221	72.37

IC50 value = 58.503 µg/mL

ExtractethanolSappan wood exhibited strong antioxidant activity with an IC50 value of 58.503 µg/mL. This value indicates good antioxidant potential for development as a natural sunscreen active ingredient.

Table 2. Antioxidant activity of quercetin

Concentration (ppm)	Sample Absorbance	% Inhibition
2	0.777	6,272
4	0.718	13,389
6	0.677	18,335
8	0.617	25,572
10	0.568	31,487

IC50 value = 15.899 µg/mL

Quercetin has higher antioxidant activity than sappanwood extract and was used as a positive comparison in this study.

SPF Value of Secang Wood Ethanol Extract

Table 3. SPF value of sappanwood ethanol extract

Concentration	SPF value
500 ppm	49.59
850 ppm	46.64
1000 ppm	45.86

The ethanol extract of sappanwood has a relatively high SPF value, ranging from 45-50, making it a potential active ingredient in sunscreen.

SPF Value of Gel Preparation

Table 4. SPF value of sappanwood ethanol extract gel preparation

Formula	SPF value
F1	20.116 ± 0.198
F2	22.355 ± 0.085
F3	19.804 ± 0.074
F4	15.110 ± 0.093

Information:
F1 = Extract 0.85%; Carbopol 0.75%
F2 = Extract 0.85%; Carbopol 1%
F3 = Extract 1.7%; Carbopol 0.75%
F4 = Extract 1.7%; Carbopol 1%

Formula F2 shows the highest SPF value compared to other formulas.

Physical Evaluation of Preparations

a. **Organoleptic**

Table 5. Organoleptic test results

Formula	Color	Smell	Consistency
F1	Red	Typical of sappanwood	Rigid
F2	Red	Typical of sappanwood	Rigid
F3	Red	Typical of sappanwood	Rigid
F4	Red	Typical of sappanwood	Rigid

All formulas had stable physical characteristics without changes in color, odor or consistency after stability testing.

b. **Homogeneity**

Table 6. Results of homogeneity test

Formula	Before	After
F1	Homogeneous	Homogeneous
F2	Homogeneous	Homogeneous
F3	Homogeneous	Homogeneous
F4	Homogeneous	Homogeneous

All four formulas meet the requirements for homogeneity of gel preparations.

c. **pH**

Table 7. pH value of the preparation

Formula	Before	After
F1	4.91 ± 0.241	4.86 ± 0.145
F2	4.70 ± 0.011	4.76 ± 0.115
F3	4.86 ± 0.026	4.88 ± 0.035
F4	4.60 ± 0.116	4.59 ± 0.134

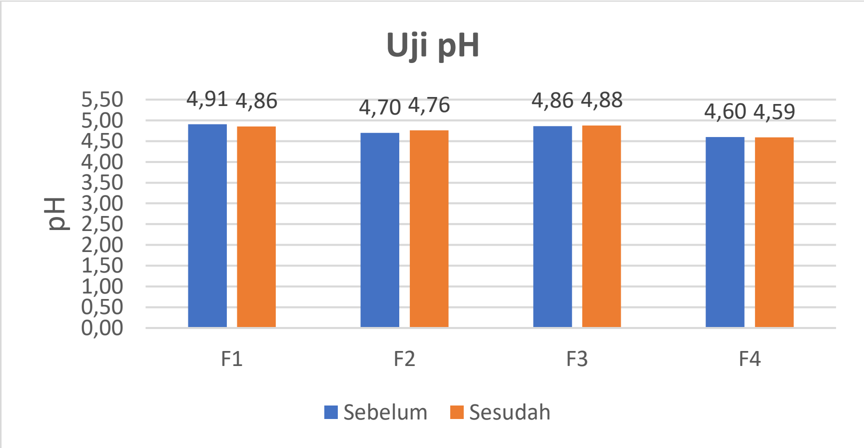

Figure 1.pH test of sunscreen gel of sappanwood ethanol extract before and after stability test

Based on table 7 and figure 1 above, it shows that all formulas have a pH according to the standard for topical preparations, namely 4.5-8.0.

d. **Syneresis**

Table 8. Percentage of syneresis

Formula	24 hours	48 hours	72 hours
F1	0.026	0.046	0.113
F2	0.047	0.113	0.193
F3	0.033	0.100	0.580
F4	0.107	0.227	0.307

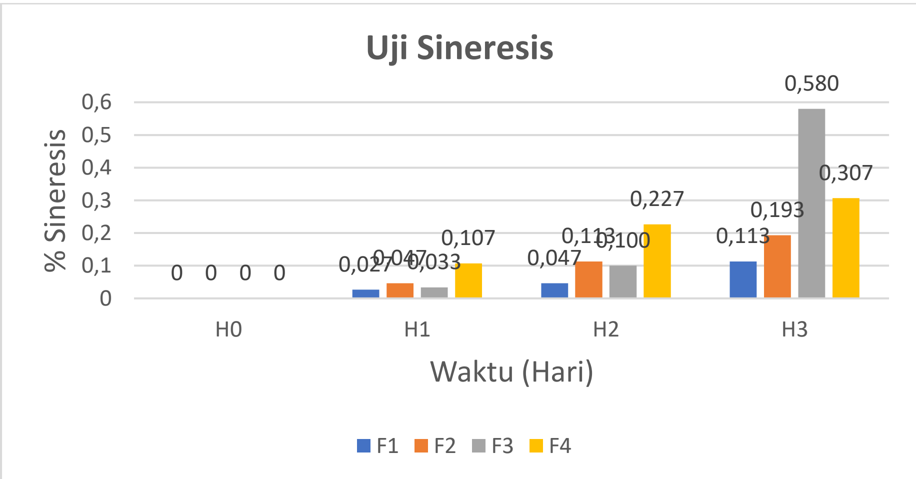

Figure 2. Syneresis test of sunscreen gel of ethanol extract of sappanwood before and after stability test

Table 8 and Figure 2 show that formula F1 shows the lowest water loss so it has better physical stability.

e. **Viscosity**

Table 9. Viscosity of gel preparations

Formula	Before (P)	After (P)
F1	149.6	142.1
F2	286.4	283.7
F3	398.9	122.8
F4	225.6	201.1

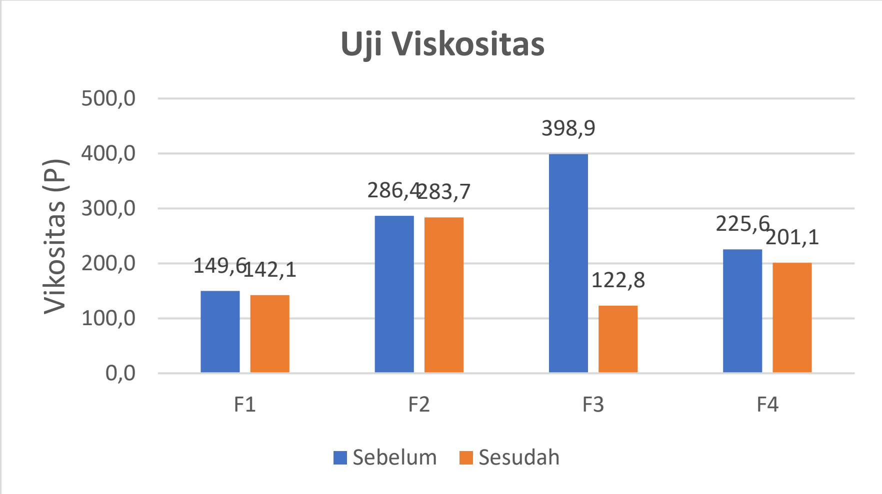

Figure 3. Viscosity test of wood ethanol extract sunscreen gel sappan wood before and after stability test

Based on table 9 and figure 3, it shows that all formulas still meet the viscosity requirements for sunscreen preparations according to SNI.

f. **Spread Power**

Table 10. Spreadability of the preparation

Formula	300 g (cm)
F1	5.38
F2	4.48
F3	4.40
F4	4.46

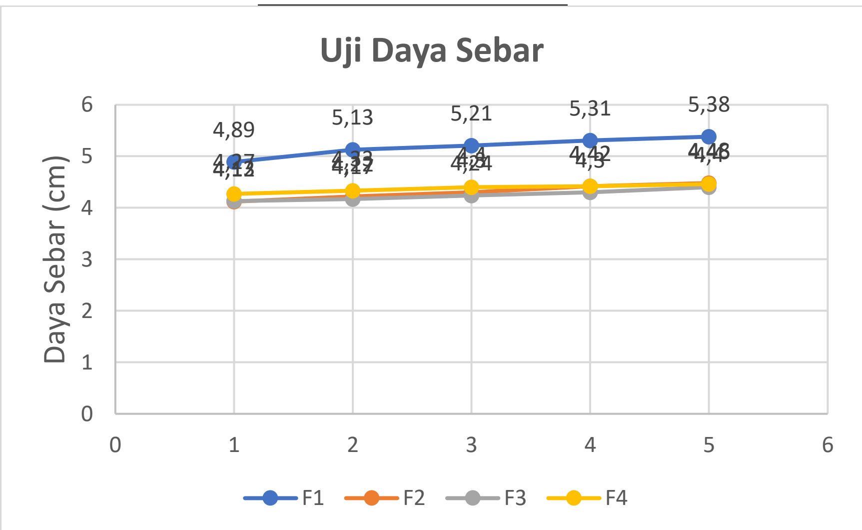

Figure 4. Spreadability test of sunscreen gel from sappanwood ethanol extract after stability test

Table 10 and Figure 4 show that formula F1 shows the best spreading power compared to other formulas.

g. **Adhesive Power**

Table 11. Adhesive power of the preparation

Formula	Adhesive Power (seconds)
F1	4.6 ± 0.577
F2	4.3 ± 0.577
F3	4.6 ± 0.577
F4	4.3 ± 0.577

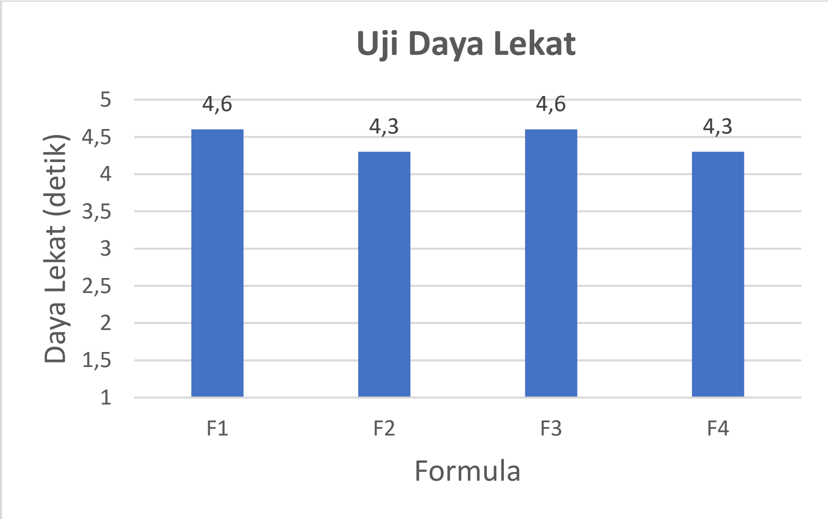

Figure 5. Adhesion test of sunscreen gel of sappanwood ethanol extract after stability test

From table 11 and figure 5 it can be seen that all formulas meet the minimum adhesive strength requirements of ≥4 seconds.

Discussion

Ethanol extract of sappan wood (Caesalpinia sappan L.) exhibited strong antioxidant activity with an IC50 value of 58.503 µg/mL. This activity is thought to originate from the presence of phenolic compounds, flavonoids, and brazilin, which act as hydrogen atom donors to neutralize free radicals. High antioxidant activity is closely related to a substance's ability to protect the skin against oxidative stress caused by ultraviolet light exposure.(Chen et al., 2021).

Measurements of the extract's SPF value showed an SPF range of 45.86-49.59, which is considered high protection. These results indicate that sappanwood extract has the ability to effectively absorb ultraviolet radiation. The presence of chromophore groups in the flavonoid and phenolic compounds allows the extract to absorb UV radiation energy, thereby reducing skin cell damage caused by sun exposure.(Fonseca et al., 2023). Sunscreen gel formulations using varying concentrations of extract and Carbopol produced SPF values between 15.11-22.35. Based on the FDA category, these values are included in the moderate to high protection category. Formula F2 provided the highest SPF value, namely 22.355 ± 0.085. These results indicate that the combination of 0.85% extract with 1% Carbopol is able to produce an optimal gel system to maintain the photoprotective activity of the active ingredients.

Physical quality testing showed that all formulas met the requirements for topical preparations. Organoleptic testing revealed no changes in color, odor, or consistency during storage. The red color is derived from brazilin, the main compound in sappanwood. The pH of all formulas ranged from 4.59 to 4.91, thus matching the physiological pH of the skin and making them safe for topical use. Homogeneity testing demonstrated an even distribution of components without any coarse particles. Physical stability was also supported by the low percentage of syneresis in all formulas, particularly F1, which had the lowest water loss.

The viscosity of the formulation was within the Indonesian National Standard (SNI) standard range for sunscreen products, while rheology tests showed a plastic flow pattern commonly found in Carbopol-based gel systems. This characteristic is important because it allows the formulation to remain stable during storage while still being easy to apply to the skin. Spreadability results showed that formula F1 had the best spreadability with a diameter reaching 5.38 cm, while all formulas had an adhesive strength above 4 seconds. These conditions indicate that the gel is able to maintain contact with the skin surface for a sufficiently long time, thus increasing the effectiveness of protection against ultraviolet radiation exposure. This study shows that the ethanol extract of sappanwood has excellent potential as an active ingredient in natural sunscreens. The formula with an extract concentration of 0.85% and Carbopol 1% produced the best balance between photoprotective activity, physical stability, and pharmaceutical characteristics that meet the quality standards for topical preparations..

5. Conclusion

This study successfully developed a sunscreen gel preparation with active ingredients of ethanol extract of sappan wood (Caesalpinia sappan L.) with varying concentrations of extract and Carbopol as a gelling agent. The ethanol extract of sappan wood showed strong antioxidant activity with an IC50 value of 58.503 μg/mL, indicating its potential as a natural antioxidant source for topical cosmetic and pharmaceutical applications. In addition, the extract has high photoprotective activity with SPF values ranging from 45.86-49.59, thus meeting the criteria as a natural sunscreen active ingredient.

The four gel formulas developed maintained good physical characteristics during storage and met the quality requirements for topical formulations. Evaluation results showed that all formulas exhibited stable, homogeneous organoleptic properties, a pH consistent with the skin's physiological pH, a viscosity that met standards, and adhesiveness and spreadability that supported comfortable application. Stability testing also demonstrated relative stability with low syneresis after accelerated storage.

The SPF value of the gel preparation ranged from 15.11-22.35 which is included in the medium to high protection category. Formula F2 containing 0.85% sappanwood extract and 1% Carbopol produced the highest SPF value of 22.355 ± 0.085 and showed good and stable physical characteristics. Overall, this study proves that the ethanol extract of sappanwood has the potential to be developed as a natural sunscreen active ingredient in the form of an effective, stable, and safe gel preparation as an alternative to synthetic sunscreens.

6. Reference

1. Abdeltawab, H., Svirskis, D., & Sharma, M. (2020). Formulation strategies to modulate drug release from poloxamer based in situ gelling systems. *Expert Opinion on Drug Delivery*, *17*(4), 495–509. https://doi.org/10.1080/17425247.2020.1731469
2. Alnuqaydan, A. M. (2024). The dark side of beauty: an in-depth analysis of the health hazards and toxicological impact of synthetic cosmetics and personal care products. *Frontiers in Public Health*, *12*, 1439027. https://doi.org/10.3389/FPUBH.2024.1439027/FULL

3. Al-Sadek, T., & Yusuf, N. (2024). Ultraviolet Radiation Biological and Medical Implications. *Current Issues in Molecular Biology 2024, Vol. 46, Pages 1924-1942*, *46*(3), 1924–1942. https://doi.org/10.3390/CIMB46030126
4. Ansarian, E., Aminzare, M., Hassanzad Azar, H., Mehrasbi, M. R., & Bimakr, M. (2022). Nanoemulsion-based basil seed gum edible film containing resveratrol and clove essential oil: In vitro antioxidant properties and its effect on oxidative stability and sensory characteristic of camel meat during refrigeration storage. *Meat Science*, *185*, 108716. https://doi.org/10.1016/J.MEATSCI.2021.108716
5. Barnes, T. M., Mijaljica, D., Townley, J. P., Spada, F., & Harrison, I. P. (2021). Vehicles for Drug Delivery and Cosmetic Moisturizers: Review and Comparison. *Pharmaceutics 2021, Vol. 13, Page 2012*, *13*(12), 2012. https://doi.org/10.3390/PHARMACEUTICS13122012
6. Bouteche, A., Touil, A., Akkal, S., Bensouici, C., & Nieto, G. (2024). Phenolic Constituents, Photoprotective Effect, and Antioxidant Capacities of Achillea ligustica All. *Molecules*, *29*(17), 4112. https://doi.org/10.3390/MOLECULES29174112/S1
7. Budzianowska, A., Banaś, K., Budzianowski, J., & Kikowska, M. (2025). Antioxidants to Defend Healthy and Youthful Skin—Current Trends and Future Directions in Cosmetology. *Applied Sciences 2025, Vol. 15, Page 2571*, *15*(5), 2571. https://doi.org/10.3390/APP15052571
8. Chen, J., Liu, Y., Zhao, Z., & Qiu, J. (2021). Oxidative stress in the skin: Impact and related protection. *International Journal of Cosmetic Science*, *43*(5), 495–509. https://doi.org/10.1111/ICS.12728;SUBPAGE:STRING:FULL
9. Eryani, M. C., Pratama, S. Y., Falahi, A., Husni, P., & Wardhani, F. A. (2025). Formulation and physical evaluation of ethanol extract gel of Jackfruit leaves (Artocarpus heterophyllus Lam.) using Carbopol as a gelling agent. *Farmasains : Jurnal Farmasi Dan Ilmu Kesehatan*, *10*(1), 14–22. https://doi.org/10.22219/farmasains.v10i1.40482
10. Fonseca, M., Rehman, M., Soares, R., & Fonte, P. (2023). The Impact of Flavonoid-Loaded Nanoparticles in the UV Protection and Safety Profile of Topical Sunscreens. *Biomolecules 2023, Vol. 13, Page 493*, *13*(3), 493. https://doi.org/10.3390/BIOM13030493
11. Hafifah, F. N., Agustina, L. S., & Latifah, N. (2025). Review Formulasi Dan Evaluasi Stabilitas Fisik Sediaan Krim Berbahan Alam: Tinjauan Berbasis Berbagai Metode Uji (Cycling, Freeze-Thaw, Sentrifugasi). *Sains Medisina*, *3*(5), 320–328. https://doi.org/10.63004/SNSMED.V3I5.738
12. Haykal, D., Lim, H. W., Calzavara-Pinton, P., Fluhr, J., Cartier, H., & Berardesca, E. (2025). The impact of pollution and climate change on skin health: Mechanisms, protective strategies, and future directions. *JAAD Reviews*, *6*, 1–11. https://doi.org/10.1016/J.JDRV.2025.05.001
13. Henderson, S. I., King, K. L., Karipidis, K. K., Tinker, R. A., & Green, A. C. (2022). Effectiveness, compliance and application of sunscreen for solar ultraviolet radiation protection in Australia. *Public Health Research and Practice*, *32*(1), 3212205. https://doi.org/10.17061/PHRP3212205/265343
14. Infante, V. H. P., Maia Campos, P. M. B. G., Calixto, L. S., Darvin, M. E., Kröger, M., Schanzer, S., Lohan, S. B., Lademann, J., & Meinke, M. C. (2021). Influence of physical–mechanical properties on SPF in sunscreen formulations on ex vivo and in vivo skin. *International Journal of Pharmaceutics*, *598*, 120262. https://doi.org/10.1016/J.IJPHARM.2021.120262
15. Insuan, W., Sillawatthumrong, N., Chahomchuen, T., Khamchun, S., Chueahongthong, F., & Insuan, O. (2024). Brazilin content and potential biological properties of Caesalpinia sappan L. heartwood extracts from different extraction methods. *Discover Applied Sciences 2024 6:10*, *6*(10), 509-. https://doi.org/10.1007/S42452-024-06222-4
16. kumar, D., Agrawal, S., Prajapati, M., Sahoo, S., & Sahoo, D. (2026). LC-MS/MS-based metabolite profiling and functional assessment of Hydrodictyon reticulatum as a potential source of natural

therapeutics collected from the Yamuna River, India. *Applied Food Research*, *6*(1), 102062. https://doi.org/10.1016/J.AFRES.2026.102062

17. Luo, Y., Liu, X. C., Li, Y. J., Wang, Y. J., Qiu, M. H., & Peng, X. R. (2025). Advances in natural products with anti-skin photoaging: mechanisms, phytochemical diversity, and therapeutic potential. *Phytochemistry Reviews 2025 25:2*, *25*(2), 1503–1528. https://doi.org/10.1007/S11101-025-10170-1
18. Mensor, L. L., Menezes, F. S., Leitão, G. G., Reyes, A. S., dos Santos, T. C., Fit, C. S., & Leitão, S. G. (2001). Screening of Brazilian plant extracts for antioxidant activity by the use of DPPH free radical method. *Phytotherapy Research*, *15*(2), 127–130. https://doi.org/10.1002/PTR.687;PAGE:STRING:ARTICLE/CHAPTER
19. Michalak, M. (2022). Plant-Derived Antioxidants: Significance in Skin Health and the Ageing Process. *International Journal of Molecular Sciences 2022, Vol. 23, Page 585*, *23*(2), 585. https://doi.org/10.3390/IJMS23020585
20. Pahlevi, M. R., Maulida, I. H., Supriadi, D., & Pratama, R. (2026). Formulation of Moringa Leaf Ethanol Extract Gel (Moringa oleifera L.) Using Carbopol 940 as a Gelling Agent and Antioxidant Activity. *Tropical Journal of Natural Product Research*, *10*(2), 7284. https://doi.org/10.26538/TJNPR/V10I2.36
21. Saryanti, D., Setiawan, I., & Dayanto, H. H. (2022). Use of CMC Na as Gelling Agent in Nanoemulgel Formulation of Methanol Extract of Sappan Wood (Caesalpinia sappan L). *Journal of Tropical Pharmacy and Chemistry* , *6*(1), 21–29. https://doi.org/10.30872/J.TROP.PHARM.CHEM.V6I1.215
22. Shi, M., Wu, S., Xie, M., Xiong, R., Yang, A., & Huang, C. (2025). A biocompatible anti-aging gel mask prepared with sappanwood extract and sodium carboxymethyl cellulose, exhibiting antioxidant and antibacterial properties. *International Journal of Biological Macromolecules*, *322*, 146588. https://doi.org/10.1016/J.IJBIOMAC.2025.146588
23. Solano, F. (2020). Photoprotection and Skin Pigmentation: Melanin-Related Molecules and Some Other New Agents Obtained from Natural Sources. *Molecules 2020, Vol. 25, Page 1537*, *25*(7), 1537. https://doi.org/10.3390/MOLECULES25071537
24. Tarumiyo, A. A., Dewi, K. H., & Asben, A. (2025). The Effect of the Addition of Green Tea Extract on the Stability of Sappan Extract Due to Ultraviolet Radiation. *AJARCDE (Asian Journal of Applied Research for Community Development and Empowerment)*, *9*(2), 296–301. https://doi.org/10.29165/AJARCDE.V9I2.697
25. Vij, T., Anil, P. P., Shams, R., Dash, K. K., Kalsi, R., Pandey, V. K., Harsányi, E., Kovács, B., & Shaikh, A. M. (2023). A Comprehensive Review on Bioactive Compounds Found in Caesalpinia sappan. *Molecules 2023, Vol. 28, Page 6247*, *28*(17), 6247. https://doi.org/10.3390/MOLECULES28176247
26. Wirawati, K. T., Ompusunggu, G. B., Wardani, L., & Yanti, K. R. D. (2023). The pharmacological potential of sappan wood (Caesalpinia sappan L.): A review of recent evidence. *Pharmacy Reports*, *3*(3), 86–86. https://doi.org/10.51511/PR.86