Trop J Nat Prod Res, January 2026; 10(1):6713 - 6719
ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Tropical Journal of Natural Product Research

Available online at https://www.tjnpr.org

Original Research Article

Optimization of Gel Formulation and Sun Protection Factor (SPF) Evaluation of *Ziziphus mauritiana* L. Ethanol Extract

Benni Iskandar[1,2,3]*, Tiara Restiana[1,2], Musyirna Rahmah Nasution[1,2], Tiara Tri Agustini[2], Ching Peng-Wei[4,5]

[1]*Department of Pharmaceutical Technology, Riau College of Pharmaceutical Sciences (STIFAR), Pekanbaru 28292, Riau, Indonesia.*
[2]*Riau College of Pharmaceutical Sciences (STIFAR), Pekanbaru 28292, Riau, Indonesia.*
[3]*MD Research ltd, 25 Indescon Square London, London-110301, United Kingdom.*
[4]*BioMed Laboratories ltd, Cardif, Wales MTWRA-2109, United Kingdom*
[5]*School of Pharmacy, College of Pharmacy, Taipei Medical University, Taipei, Taiwan*

ARTICLE INFO

Article history:
Received 29 September 2025
Revised 12 December 2025
Accepted 31 December 2025
Published online 01 February 2026

ABSTRACT

The use of natural ingredients as sunscreen agents is being increased in response to the demand for safe and environmentally friendly skin care products. *Ziziphus mauritiana* L. extract contains flavonoid compounds with UV-absorbing activity, but investigations on optimizing its formulation in sunscreen gel remain limited. Therefore, this study aimed to evaluate the effects of varying concentrations of Carbopol 940 and triethanolamine (TEA) on physical characteristics and UV protection activity of *Ziziphus mauritiana* L. extract-based sunscreen gel, as well as to determine the optimal formula. The method adopted was an experiment using Box–Behnken Design (BBD) with Design Expert software. Gel formulations were prepared with Carbopol 940 (0.5–2%) and TEA (0.5–1%). The results showed that the optimal formula predicted by the software contained 0.598% Carbopol 940 and 0.522% TEA. This met the requirements for topical formulations, with no irritation. The percentage error between predicted and experimental results was 0.9% for pH and 3.71% for spreadability, both within the ±<10% tolerance limit. The optimal formula featured an SPF (Sun Protection Factor) value of 18.92 at week 1 and 18.45 at week 4, classified as ultra-protection. These results suggest that the appropriate combination of Carbopol and TEA produced a *Ziziphus mauritiana* extract sunscreen gel with favorable physical properties and strong UV protection. Optimization using an experimental design method provided significant outcomes for developing natural sunscreen formulations.

***Keywords*:** *Ziziphus mauritiana* L, sunscreen gel, Sun Protection Factor, Box-Behnken Design, optimization.

Introduction

Tropical regions receive some of the highest levels of solar radiation, and people living in these areas are frequently exposed to sunlight during daily activities. Excessive exposure may lead to both acute and chronic effects, including erythema, decreased skin elasticity, and increased risk of skin cancer. Although melanin provides a natural defense mechanism, its protective capacity decreases with increasing ultraviolet (UV) intensity, requiring additional protection such as the use of sunscreen.[1,2]

In recent years, natural ingredients have attracted growing interest in cosmetic formulations due to a better safety profile compared to synthetic compounds, which may cause skin irritation or other adverse effects.[3] A promising plant is *Ziziphus mauritiana* L., containing flavonoids, alkaloids, saponins, steroids, and tannins. Among these bioactive compounds, flavonoids are of particular importance because the chromophore groups enable absorption of UVA and UVB, thereby reducing UV-induced damage.

*Corresponding author. Email: benniiskandar@stifar-riau.ac.id
Tel: +6285271776535

Citation: Iskandar B, Restiana T, Nasution MR, Agustini TT, Peng-Wei C. Optimization of Gel Formulation and Sun Protection Factor (SPF) Evaluation of *Ziziphus mauritiana* L. Ethanol Extract. Trop J Nat Prod Res. 2026; 10(1): 6713 – 6719 https://doi.org/10.26538/tjnpr/v10i1.40

Official Journal of Natural Product Research Group, Faculty of Pharmacy, University of Benin, Benin City, Nigeria

Previous studies reported antioxidant activity of the methanol extract with an IC50 of 33.48 µg/mL compared with vitamin C (6.42 µg/mL). Sunscreen activity of ethanol extract was also documented with SPF (Sun Protection Factor) values of 11.561–15.741.[4,5]

Gel was selected as the formulation base because of its favorable properties, including good skin absorption, cooling effect, easy spreadability, and lack of residue.[6] Previous studies have shown the suitability of hydroxypropyl methylcellulose (HPMC) as a gelling agent. However, the use of Carbopol 940, in combination with triethanolamine (TEA) as a neutralizing agent, remains underexplored. Carbopol 940 forms a clear, stable gel with good spreadability, and TEA adjusts pH into the skin-compatible range.[7] Based on the rationale, this present study aimed to optimize the gel formulation of ethanol extract of *Ziziphus mauritiana* L. using Carbopol 940 and TEA with Design Expert 13 software. In the process, SPF values of the resulting formulations were also evaluated. This result is expected to provide a basis for the development of natural, gel-based sunscreen products and contribute to the utilization of local natural resources in the cosmetic industry.[8]

Materials and Methods

Phytochemical screening of Ziziphus mauritiana L. extract

A total of 0.5 g of the extract was mixed with 5 mL of distilled water and 5 mL of chloroform. The mixture was vigorously shaken and allowed to stand until two distinct layers formed, which were then separated. The aqueous (upper) layer was used to test for phenolic compounds, saponins, and flavonoids, while the chloroform (lower) layer was analyzed for the presence of terpenoids and steroids.[9]

Determination of SPF Value of Ziziphus mauritiana L. Ethanol Extract
The extracts were weighed at 50 mg and diluted with p.a. ethanol to 50 mL to obtain a 1000 ppm stock solution. To obtain concentrations of 300 ppm, 400 ppm, 500 ppm, and 700 ppm, the solution was pipetted and transferred into a 10 mL volumetric flask. Before this process, the spectrophotometer was calibrated using 96% ethanol. The absorbance was measured at wavelengths of 290–320 nm using ethanol as the blank, and reading was taken every 5 nm. Subsequently, the values obtained were multiplied by EE × I for each interval. The total EE × I was multiplied by the correction factor to obtain the SPF value of the extract.[4,7]

Optimized Design of Ziziphus mauritiana L. Extract Gel Formulation
A Box-Behnken statistical design alongside 2 factors and 17 experiments was selected for the optimization with the help of Design Expert 13 software. The variables were modified from Suhartinah's 2022 study, including the percentage of Carbopol 940 and TEA, which were the main components of gel formation. The dependent variables or responses were pH and the spreadability test.

Response Testing
The following are the several stages of the test that evaluate the gel preparation used as the dependent variable:

pH Test
pH was checked using the respective meter, which was calibrated with standard buffer solutions of pH 4, 7, and 10. The electrode was rinsed with distilled water, dried, and immersed in the formulation until a constant value appeared on the meter. Furthermore, the number shown by the instrument was the value of the gel formulation. The test was performed three times, and the pH range for the face was 4.5–6.5.

Spreadability Test
Approximately 0.5 grams of the sample was placed on a transparent glass plate lined with graph paper, left for a moment (15 seconds), and a specific weight (in grams) was applied on the top. The area covered by the gel sample was then measured, and the test was repeated three times (replicates).[9]

Validation of Formula Optimization Model
The parameters for formulating ethanol extract gel from *Ziziphus mauritiana* L. were optimized using Design Expert by specifying selection criteria for the optimal concentrations of Carbopol and TEA. The response variables measured were pH and spreadability. Desirability is a function that reflects the program's ability to achieve the set optimization criteria for the final product. A value of 0.9 out of 1.0 showed a high probability of producing the desired formulation, while a value of 1.0 signified that the optimization goal had been fully achieved.[1,8]

Evaluation of Optimum Gel Preparation
The following are the several stages of the test that evaluate the gel preparation:

Organoleptic Test
An organoleptic test was conducted to observe the physical form of the gel preparation. The examination of shape, odor, and Colour was performed visually on the preparation. It was conducted weekly for 4 weeks of storage at room temperature.[10]

Homogeneity Test
Homogeneity of the gel formulation was evaluated by placing 0.25 g of the sample on a glass plate before being covered. The plates were pressed and rubbed to assess whether the formulation was uniform in texture. This test was conducted weekly over 4 weeks during storage at room temperature.[3,7]

pH Test
pH was checked using the respective meter, which was calibrated with standard buffer solutions of pH 4, 7, and 10. The electrode was rinsed with distilled water, dried, and immersed in the formulation until a constant value appeared on the meter. Furthermore, the number shown by the instrument was the value of the gel formulation. The test was performed three times, and the pH range for the face was 4.5–6.5.[11]

Spreadability Test
Approximately 0.5 grams of the preparation was placed on a transparent glass covered with graph paper. It was left for a moment (15 seconds), the area covered by the gel preparation was calculated, and a transparent plastic was used as a cover. A specific weight (in grams) was then applied on top and left for 60 seconds. The increase in area provided by the gel was measured, and this process was repeated three times.[7]

Adhesion Test
An adhesion test was conducted by placing 0.5 grams of gel on an object glass, then covering it with another object glass, and applying a 1 kg weight for 3 minutes. Adhesion strength was determined by the time required for the two glasses to separate. The requirement was more than 4 seconds, with the process repeated three times (replication). The examination was conducted weekly over a 4-week storage period at room temperature.[12]

Viscosity Test
Viscosity measurement was performed using a Brookfield viscometer. The gel formulation was placed in a 100 ml beaker and kept in a special container. The spindle used for viscosity measurement was spindle 4, and the speed was set at 30 rpm, adjusted to the gel formulation. Additionally, the viscometer was run, and the gel viscosity was observed and recorded, with the examination process being conducted three times.[13]

Heating-Cooling Stability Test
The heating and cooling method included weighing 5 g of gel from each formulation and placing it in tightly sealed vials. Each vial underwent a heating–cooling cycle consisting of storage at 4°C for 24 hours, followed by storage at 40°C for 24 hours. Based on observation, a complete sequence constituted a single cycle. The procedure was repeated for six cycles, during which organoleptic properties, homogeneity, and pH were evaluated after each cycle. The formulation was considered stable when no changes in these parameters were observed after six cycles.[13,14]

Skin Irritation Test
A skin irritation test was performed as a closed patch test on human skin. The procedure includes applying 0.1 g of the gel formulation to the inner part of the arm with a diameter of 2 cm. Subsequently, the formulation was covered using a bandage and sealed with adhesive tape for 24 hours. The appearance of any symptoms, such as redness or itching, should be observed. During the process, the irritation test was performed on a panel of 3 people.[7,12] This study was approved for ethical clearance with number 506/KEP-UNIVRAB/III/2025 from the Faculty of Medicine Abdurrab University, Indonesia.

Sunscreen Activity Test
Preparation of Sunscreen Activity Test Solution
A total of 2 grams of the sample was weighed and placed in a 10 ml measuring flask before dissolving with p.a. ethanol up to the mark. In the process, SPF value and %Te and %Tp were determined.[15]

SPF Value
SPF value was calculated using Mansur's equation. The solution obtained was tested by a UV-Vis spectrophotometer with a blank of ethanol p.a. at a wavelength of 290-320 nm. Furthermore, the absorption value obtained was multiplied by EE X I for each interval. The total EE × I was multiplied by the correction factor to obtain the SPF value of the gel formulation.[16]

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

%Te ***(Transmission of erythema) Value***
%Te value was determined using a UV-Vis spectrophotometer by measuring transmittance (T) at wavelengths of 292.5–317 nm in 5 nm intervals with ethanol p.a. as the blank.[17]

%Tp ***(Transmission of pigmentation) Value***
%Te value was determined using a UV-Vis spectrophotometer by measuring transmittance (T) at wavelengths of 292.5–317 nm at 5 nm intervals with ethanol p.a. as the blank.[18]

Data Analysis
The test data were processed using Design Expert 13 software and Response Surface Methodology to obtain the optimum formula based on the parameters of pH and spreading power. The data were presented in tables and figures to conclude the effect of concentration differences on the use of Carbopol 940 and TEA in ethanol leaf extract gel preparations. Subsequently, the data were analyzed descriptively in the form of SPF value calculations and analysis using One-Way Analysis of Variance (ANOVA) statistics.

Result and Discussion

Phytochemical screening of Ziziphus mauritiana L. extract
The results of this phytochemical screening are presented in Table 1. The screening results of the ethanol extract of *Ziziphus mauritiana* L. showed the presence of flavonoids, phenolics, saponins, terpenoids, and steroids. *Ziziphus mauritiana* L. had a high flavonoid content, functioning as a reducing agent that inhibited several oxidation reactions. [2,5,6]

Determination of SPF Value of Ziziphus mauritiana L. Ethanol Extract
The results of testing the sunscreen activity of ethanol extract from *Ziziphus mauritiana* L. obtained by calculating SPF index, are presented in Table 2. Based on the evidence, the ethanol extract of *Ziziphus mauritiana* L. had a sufficient SPF value to be used in the formulation of a sun gel.

Table 1: Results of Phytochemical Screening of Ethanol Extracts from Ziziphus mauritiana L.

Phytoconstitutents	Result	Reaction
Flavonoid	+	Red Colour formed
Fenolik	+	Blackish green Colour formed
Saponin	+	Stable foam formed
Terpenoid	+	Brownish red Colour formed
Steroid	+	Blue/green Colour formed

Table 2: SPF Value of *Ziziphus mauritiana* L. Ethanol Extract

Concentration (µg/mL)	SPF Value	Category
300	8.00	Extra protection
400	10.75	Maximum protection
500	12.81	Maximum protection
700	15.30	Ultra protection

Optimized Design of Ziziphus mauritiana L. Extract Gel Formulation
Formula optimization was performed by entering the variable data into Design Expert software version 13. The variables in this study were the concentrations of Carbopol 940 (0.5-2%) and TEA (0.5-1%). The data was entered into Design Expert software version 13, which generated 17 formulas with varying variable concentrations. Furthermore, the response of each formula was evaluated based on pH and spreadability. The formula predictions by Design Expert 13 software are shown in Table 3.

Response Testing
The optimal formula recommended by Design Expert software was determined based on the highest desirability contour plot. The desirability value is directly proportional to the suitability of the product formula to achieve the optimal formula with the specified response variables. In this study, a value of 1.000 was obtained for the recommended optimal formula, corresponding to a composition of Carbopol 940 = 0.598% and TEA = 0.522%, with predicted response values of pH = 5.936 and spreadability = 5.488. Subsequently, the ethanol extract gel formula from *Ziziphus mauritiana* L. was re-formulated for verification based on the response parameters used, namely pH testing and spreadability.[4,16]

Validation of Formula Optimization Model
The predictions of the response values of the optimization results provided by the design expert program were verified. The actual response values obtained from the verification stage are compared with the response predictions generated by the design expert program.[7,12] Furthermore, the results for the optimal ethanol extract formula of *Ziziphus mauritiana* L. produced a pH error of 0.9% and a spreadability of 3.71%, as detailed in Table 4. This shows that there is no significant difference since the error was in ±10%.

Table 3: Formula 17 run and response results using Box-Behnken Design

Run	Factor 1 A:Carbopol 940	Factor 2 B:TEA	Response 1 pH	Response 2 Spreadibility
1	2	1	5.47	3.60
2	1.25	0.75	5.83	4.10
3	1.25	0.75	5.83	4.10
4	2	0.75	4.72	3.90
5	0.50	0.75	6.72	5.50
6	1.25	0.50	5.07	4.30
7	1.25	0.75	5.83	4.10
8	1.25	0.75	5.83	4.10
9	0.50	1	7.40	5.70
10	2	0.75	4.72	3.90
11	0.50	0.75	6.72	5.50
12	2	0.50	4.43	4.90
13	0.50	0.50	5.94	6
14	1.25	0.75	5.83	4.10
15	1.25	1	6.95	4.20
16	1.25	1	6.95	4.20
17	1.25	0.50	5.07	4.30

Based on the results, different contours and Colours were observed for each response. The contour plot showing red and blue signifies the maximum and minimum response, respectively. Blue suggested low pH areas, while red reflected higher pH areas. This contour pattern showed that the synergistic increase in the concentration of both components enhanced the pH value of the gel formulation. In the dispersion capacity contour plot diagram, the Colour gradient from blue to orange represented an elevation in dispersion capacity as the concentration of Carbopol 940 increased (Figure 1).[19]

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

Table 4: Optimum Formula Verification Results

Preparation Evaluation	Prediction Design Expert 13	Average SD ± SD Observation	% error
pH	5.936	5.99±0.02	0.90%
Spreadibility test	5.488	5.7±0.20	3.71%

The interaction between factors, namely the concentration of Carbopol 940 and TEA on pH and spreadability, was determined using Design Expert software version 13 (Figure 2). An increase in the concentration of Carbopol 940 tends to decrease the pH value, both at low (black line) and high (red line) concentrations of TEA. This showed that Carbopol 940 influenced pH reduction, while TEA played a role in increasing the pH of the formulation. The interaction between these two ingredients determined the pH stability of the formulation, where an increase in Carbopol without being balanced by TEA led to a significant decrease. Conversely, at higher TEA concentrations, the decrease caused by Carbopol was suppressed, resulting in a more stable value in an appropriate range for topical use.[19,20]

Increasing the concentration of Carbopol 940 tends to reduce the spreadability value, both at low (black line) and high (red line) TEA concentrations. This is in line with Carbopol's characteristics as a gel-forming agent that increases system viscosity, thereby limiting the mobility and spread of the formulation on the skin surface.[21]

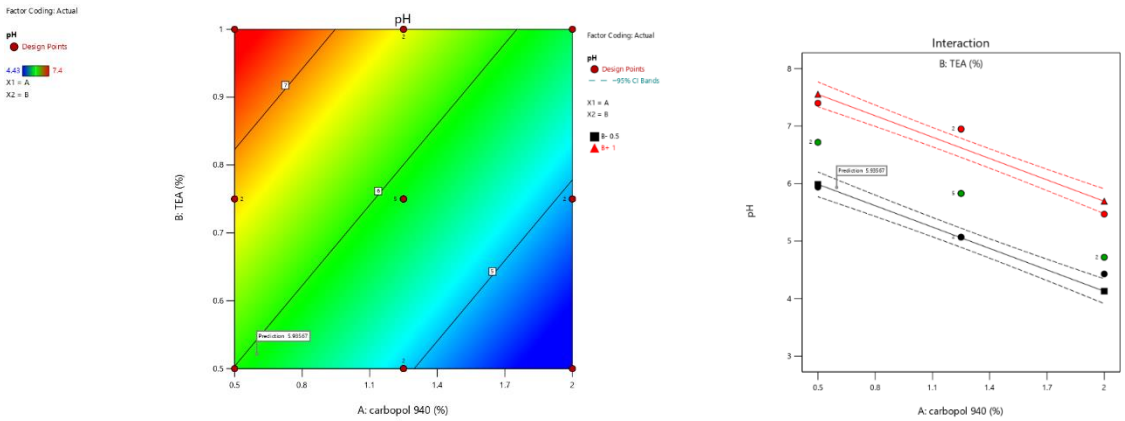

Figure 1: Contour Plot Result and Interaction Curve of Carbopol 940 and TEA Against pH

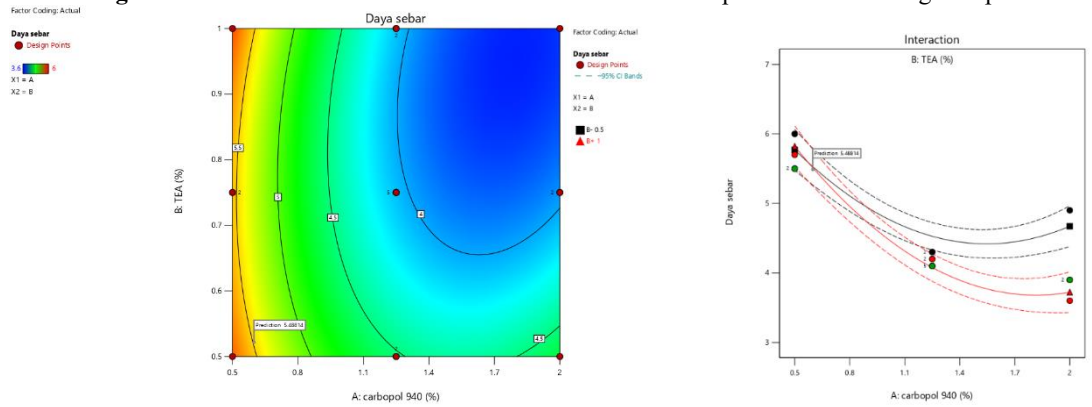

Figure 2: Contour Plot Results and Interaction Curve of Carbopol 940 and TEA on Spreadability

Evaluation of Optimum Gel Preparation

Organoleptic Test

The results of the organoleptic test on the shape, Colour, and odor of the optimal formulation are shown in Table 5. Based on observations conducted over 4 weeks, the gel formulation did not undergo changes and remained stable during 4 weeks of storage.

Homogeneity Test

Homogeneity test of the gel preparation showed no particles in the optimal gel formula of ethanol extract of *Ziziphus mauritiana* L. (Table 6). A homogeneous preparation was characterized by the absence of clumped particles or coarse granules in the preparation.

pH Test

The gel formulation was designed to maintain a normal skin pH between 4.5 and 6.5. In this context, Carbopol has a naturally acidic pH, between 2.5 and 4.5. Excessive acidity can irritate, while an alkaline environment can lead to dryness, sensitivity, and an increased risk of infection (Figure 3). During the four-week storage period at room temperature, fluctuations were observed as detailed in Table 7, attributed to the hydrolysis of acidic compounds, which induced a slight decrease in pH.[22] The data for the optimal formulation followed a normal distribution ($p > 0.05$). A one-way ANOVA showed a significant change in pH during the storage period ($p = 0.004$). However, pH change remained minimal and in the acceptable range for the skin.[11,23]

Spreadability Test

The spreadability test aims to determine how well the gel formulation spreads across the skin surface. A good spreadability facilitates application, ensuring more even distribution of the active ingredient, thereby optimizing the effects. This test is conducted weekly over a 4-week storage period as detailed in Figure 4, and the results are shown in Table 8. Based on observation, a decrease occurs each week, which may be due to the storage period affecting the gel's spreadability in an inverse proportion. This is because the water content in the gel formulation evaporates, causing the formulation to become increasingly viscous.[24]

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

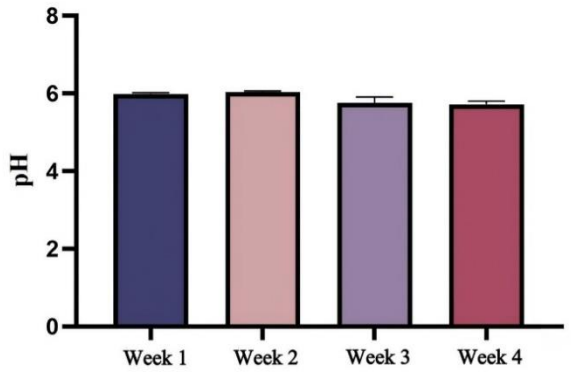

Figure 3: pH Test

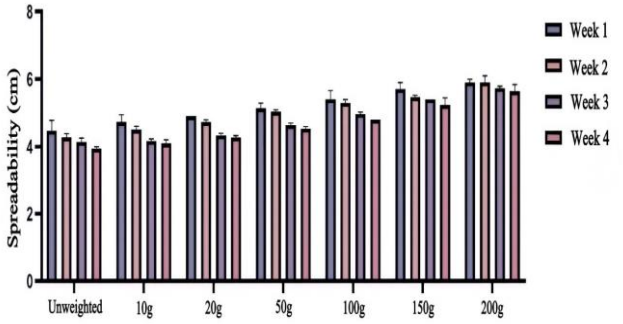

Figure 4: Spreadability Test

Adhesion Test

Adhesion test, as detailed in Figure 5, correlated with the duration of gel adhesion to the skin, enabling the penetration of the active ingredients contained in the preparation. The test measured the gel's adhesion to the skin during use, which reflected the formulation quality. It was evaluated weekly over a 4-week storage period to assess the effect of prolonged storage. Adhesion strength results from week 1 to week 4 (Figure 5) showed a slight increase. This was because the ethanol extract gel of *Ziziphus mauritiana* L., after being stored for 4 weeks, became thicker in consistency. The phenomenon can also be attributed to Carbopol, which absorbs water from outside the globules, making the formulation thicker. Based on observation, spreadability is inversely correlated with adhesive strength.[25,26]

Table 5: Organoleptic Test

Formula	Colour	Aroma	Texture
Optimum Formula	Yellowish green	characteristic smell of *Ziziphus mauritiana* L.	Semi-solid preparation (gel)

Table 6: Homogeneity Test

Optimum Formula	Result
Week 1	Homogeneous
Week 2	Homogeneous
Week 3	Homogeneous
Week 4	Homogeneous

Viscosity Test

Viscosity test results are presented in Figure 6, where an increase during storage time may be due to polymer development in the gel formulation. This contributed to increased interpolymer bond density during storage, causing the gel formulation to become thicker. Additionally, changes in viscosity in the gel formulation may be attributed to the presence of air bubbles trapped during preparation. Air bubbles in the gel formulation affect viscosity values in a direct proportionality. The high viscosity of the ethanol extract gel from *Ziziphus mauritiana* L. is the cause of low spreadability. The concentration of Carbopol as a gelling agent also determines spreadability capacity.

Table 7: Heating-cooling stability test

Test	Texture	Smell	Colour
1 cycle	Semi-solid (gel)	Typical *Ziziphus mauritiana* L.	Yellowish green
2 cycles	Semi-solid (gel)	Typical *Ziziphus mauritiana* L.	Yellowish green
3 cycles	Semi-solid (gel)	Typical *Ziziphus mauritiana* L.	Yellowish green
4 cycles	Semi-solid (gel)	Typical *Ziziphus mauritiana* L.	Yellowish green
5 cycles	Semi-solid (gel)	Typical *Ziziphus mauritiana* L.	Yellowish green
6 cycles	Semi-solid (gel)	Typical *Ziziphus mauritiana* L.	Yellowish green

Table 8: Sunscreen Test Results Based on %Te, %Tp, and SPF Value

Optimum Formula During Storage	% Te	% Tp	SPF	Category SPF Value
Week 1	1.5	2.57	18.92	Ultra Protection
Week 4	1.6	2.87	18.45	Ultra Protection

Heating-Cooling Stability Test

Heating-cooling stability test aims to determine whether there is phase separation of the gel preparation under extreme temperatures. At the end of each cycle, the preparation is examined for phase separation, and observations are made regarding organoleptic properties, pH, and spreadability. Based on the organoleptic examination, from cycle 1 to cycle 6, the formulation remained stable without any phase separation and no changes in physical appearance, shape, odor, Colour, and a homogeneous composition (Figure 7). This suggests that all the ingredients used in the gel formulation are well mixed, ensuring the formulation remains stable under extreme temperature conditions.

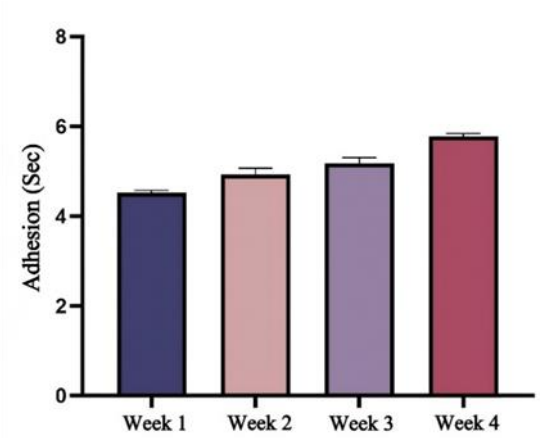

Figure 5: Weekly Adhesion Test Results of the Optimized Gel Formulation

ISSN 2616-0684 (Print)
ISSN 2616-0692 (Electronic)

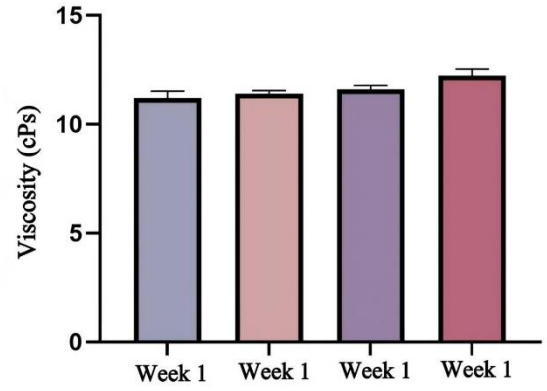

Figure 6: Weekly Viscosity Test Results of the Optimized Gel Formulation

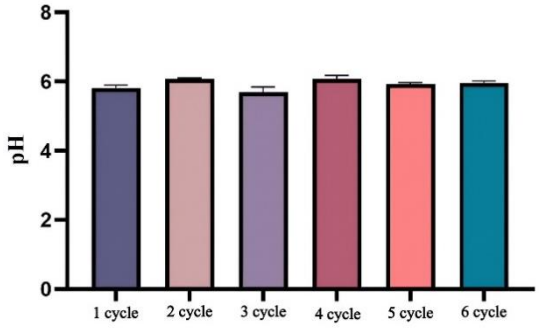

Figure 7: pH Stability Test

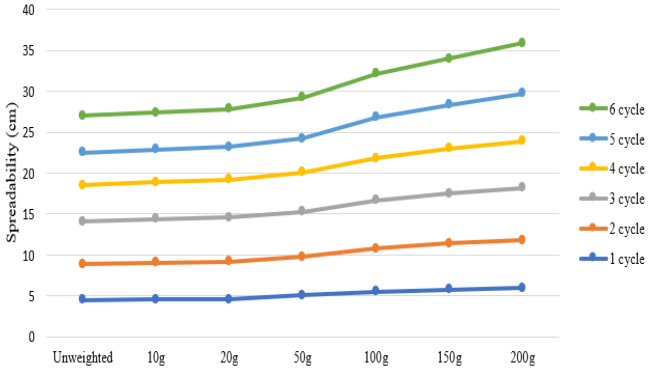

Figure 8: Stability Test of Spreadability

pH measurement of ethanol extract gel preparation from Ziziphus mauritiana L. in heating-cooling test conducted over 6 cycles showed an increase and decrease (Figure 7). However, the requirements for gel preparations, which were 4.5-6.5, were still met. The decrease in pH occurred because Carbopol 940 dispersed in water, forming an acidic colloid. Storage conditions of Carbopol 940 can affect its stability, leading to a decrease in pH values. The instability of the gel network structure contributes to pH imbalance between cycles, although the value generally remains in the acceptable range for topical formulations.[27]The spreadability of ethanol extract gel preparations from Ziziphus mauritiana L. was assessed in a heating-cooling test conducted over 6 cycles. The results showed fluctuations in the gel formulation in each cycle (Figure 8), which occurred due to the influence of storage temperature. Temperature changes altered the viscosity, thereby affecting its spreading ability.

Skin Irritation Test

Skin irritation test of ethanol extract gel from *Ziziphus mauritiana* L. was performed on three panelists using the closed patch method to determine the optimal formula. Signs of irritation, such as redness, itching, or swelling on the inner arm, would have shown a positive reaction. However, observations of both formulas presented no allergic responses in any panelist, as no redness, itching, or burning sensations were detected. These results suggest that the developed formulation was safe for topical use.[11]

Sunscreen Activity Test

This study showed sunscreen activity based on SPF, %Te, and %Tp values measured at weeks 1 and 4 during storage at room temperature (Table 14). For the optimal formula, SPF values were 18.92 at week 1 and 18.45 at week 4, both categorized as ultra protection. %Te values were 1.5 at week 1 and 1.6 at week 4, reflecting extra protection against erythema and pigmentation. This contributed to minimal erythema without pain and the prevention of skin darkening upon sun exposure. %Tp values were 2.57 (week 1) and 2.85 (week 4), both classified as sunblock. This represented the most effective sunscreen activity by blocking UVA and UVB penetration and simultaneously preventing erythema and pigmentation. An effective sunscreen formulation was characterized by a high SPF with low erythema and pigmentation transmission. The results confirmed that the developed formulation met the requirements, providing strong protection against both UVB and UVA radiation.[28,29]

The statistical test results of SPF values for the optimal formula showed that the data were normally distributed ($p > 0.05$). One-way ANOVA test was then conducted, with the significance value of the optimal formula being 0.000 ($p < 0.05$). This suggested a statistically significant difference between SPF values at week 1, week 4, the negative control, and the positive control. As a result, the differences between groups remained significant after 4 weeks of storage.[29]

Conclusion

The optimal gel formulation of ethanol extract from *Ziziphus mauritiana* L. was obtained using the experimental design approach with Design Expert 13, incorporating Carbopol 940 (0.5%) and TEA (0.5%). This formulation met the criteria for topical preparations based on physical evaluation and showed no signs of skin irritation. pH %error (0.9%) and spreadability (3.71%) remained in the ±10% tolerance range, confirming consistency between predicted and actual outcomes. The optimized gel featured sunscreen activity with an SPF value categorized as ultra-protection and showed statistical stability during storage. Therefore, the developed gel formulation presents favorable physical characteristics, stable natural sunscreen properties, and potential for advancement as a herbal-based cosmetic product.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

Acknowledgments

The authors are grateful for the 2025 Internal Grants from P3M Riau College of Pharmaceutical Sciences (STIFAR), with grant number 001a.P3M.STIFAR.VIII.2025.

References

1. Xenakis A, Galani E, Papadimitriou V, Chatzidaki MD. Soft nanostructures for sun protection formulations. Cur Opin Colloid Interface Sci. 2024;71**:** 101803.
2. Bell LW, Hossang EY, Traill SR, Dalgliesh NP, Budisantoso E, Nulik J. Short phases of tropical forage legumes increase

production of subsequent cereal crops in the seasonally dry tropics of eastern Indonesia. Eur J Agron. 2022;132**:** 126406.
3. Charaabi S, Issa S, Pensé-Lhéritier AM, Borgne ML. Kinetics of benzophenone-3 release from clay minerals or organosilicates for sun protection formulation. Int J Pharm. 2025;682**:**125920.
4. Rahman A, Tan AL, Harunsani MH, Ahmad N, Hojamberdiev M, Khan MM. Visible light induced antibacterial and antioxidant studies of ZnO and Cu-doped ZnO fabricated using aqueous leaf extract of Ziziphus mauritiana Lam. J Environ Chem Eng. 2021;9**:**105481.
5. Paudel MR, Poudeyal MR, Devkota HP. Ziziphus spp. (Ziziphus jujuba Mill., Ziziphus mauritiana Lam.). In: Belwal T, Bhatt I, Devkota H, editors. Himalayan Fruits and Berries. Academic Press. London: Academic Press; 2023.
6. Cranage MP, Fraser CA, Cope A, Mckay PF, Seaman MS, Cole T, Mahmoud AN, Hall J, Giles E, Voss G, Page M, Almond N, Shattock RJ. Antibody responses after intravaginal immunisation with trimeric HIV-1CN54 clade C gp140 in Carbopol gel are augmented by systemic priming or boosting with an adjuvanted formulation. Vaccine. 2011;29:1421-1430.
7. Chaudhary H, Rohilla A, Rathee P, Kumar V. Optimization and formulation design of carbopol loaded Piroxicam gel using novel penetration enhancers. Int J Biol Macromol. 2013;55**:**246-253.
8. Parveen SR, Wadhwa S, Babu MR, Vishwas S, Corrie L, Awasthi A, Khan FR, Al-Bazi MM, Alharthi NS, Alotaibi F, Gupta G, Pandey NK, Kumar B, Kumbhar P, Disouza J, Gulati M, Neelamraju J, Madempudi RS, Dua K, Singh SK. Formulation of chrysin loaded nanostructured lipid carriers using Box Behnken design, its characterization and antibacterial evaluation alone and in presence of probiotics co-loaded in gel. J Drug Deliv Sci Technol. 2023;84**:**104411.
9. Pfoze BK, Singh RR, Pekosii BK, Singh TP, Singh OM. Phytochemical screening and assessment of the in-vitro wound healing activity of Bidens pilosa leaves. Pharmacol Res Nat Prod. 2025;8**:**100331.
10. Lorquin F, Lorquin J, Claeys-Bruno M, Rollet M, Robin M, Di Giorgio C, Piccerelle P. Lignosulfonate is an efficient SPF booster: Application to eco-friendly sunscreen formulations. Sustain Chem Pharm. 2021;24**:**100539.
11. Iskandar B, Mei HC, Liu TW, Lin HM, Lee CK. Evaluating the effects of surfactant types on the properties and stability of oil-in-water Rhodiola rosea nanoemulsion. Colloids Surf B Biointerfaces. 2024;234**:**113692.
12. Darmawan MA, Ramadhani NH, Hubeis NA, Ramadhan MYA, Sahlan M, Abd-Aziz S, Gozan M. Natural sunscreen formulation with a high sun protection factor (SPF) from tengkawang butter and lignin. Ind Crops Prod. 2022;177**:**114466.
13. Nascimento Júnior JAC, Oliveira AMS, Santos AM, Santana Júnior CC, Morawski AS, Souza PDB, Paese K, Ribeiro JG, Rosa DDS, Araújo AADS, Aragón DM, Frank LA, Serafini MR. Enhanced skin photoprotection integrating a spray-dried hesperetin nanocapsules semisolid formulation: Development of the formulation and clinical trial study. Colloids Surf B Biointerfaces. 2025;256**:**114990.
14. Leny, Sari M, Ginting M, Melisa, Iskandar B. Evaluation Of An Anti-Dandruff Shampoo Incorporating Ethanol Extract From Corn Silk (Zea mays L.) Against Candida Albicans Fungus: Formulation and Activity Assessment. Int J Appl Pharm. 2024;16**:**48-56.
15. Zhang Y, Zhang J, Li J, Shen J, Zhang X. Thermosensitive ZnO-PMMA/PEG microgels: A smart sunscreen with adapting SPF to ambient temperature fluctuations. Mater Today Chem. 2024;37**:**102039.
16. Bai X, Yan J, Gilchrest BA. Next-Generation Zinc Oxide–Based Sunscreens: Molecular Characteristics and Advantages. J Invest Dermatol. 2024;144**:**430-434.e1.
17. He H, Li A, Li S, Tang J, Li L, Xiong L. Natural components in sunscreens: Topical formulations with sun protection factor (SPF). Biomed Pharmacother. 2021;134**:**111161.
18. Dong X, Woo C, Lee M, Shin K, Yu HK, Choi JY. Optimized encapsulation of bis-ethylhexyloxyphenol methoxyphenyl triazine (BEMT) in porous silica for enhanced UV protection and stability. Microporous Mesoporous Mater. 2025;397**:**113763.
19. Biswas S, Mukherjee PK, Kar A, Bannerjee S, Jana SN, Haldar PK, Sharma N. Enhanced permeability and photoprotective potential of optimized p-coumaric acid-phospholipid complex loaded gel against UVA mediated oxidative stress. J Photochem Photobiol B Biol. 2021;221**:**112246.
20. Chen C, Ma X, Wan Y, Zhong Y, Hou X, Fang H, Liang T. Design, synthesis and evaluation of structural optimization derived HDAC6 isoform-selective inhibitor. Bioorg Chem. 2025;161**:**108562.
21. Fang Q, Xu T, Su R, Dai S, Wang J, Zhu W, Yang B, Tong X, Wang H Jiang L. Composite gel based on κ-carrageenan-soybean isolate protein/soy protein fibrils: Focus on structural differences and gel properties. Int J Biol Macromol. 2025;307**:**142274.
22. Da Silva VV, Ropke CD, De Almeida RL, Miranda DV, Kera CZ, Rivelli DP, Sawada TCH, Barros SBM. Chemical stability and SPF determination of Pothomorphe umbellata extract gel and photostability of 4-nerolidylcathecol. Int J Pharm. 2005;303**:**125-131.
23. Chamsai B, Rangsimawong W, Suriyaamporn P, Opanasopit P, Samprasit W. Development of radish extract-loaded transfersomes blended sunscreen formulation for tyrosinase melanin and photoprotective sunscreening effect. J Drug Deliv Sci Technol. 2024;101**:**106230.
24. Rao MRP, Gaikwad P, Misal P Gandhi SV. Phyto-cosmeceutical gel containing curcumin and quercetin loaded mixed micelles for improved anti-oxidant and photoprotective activity. Colloids Surf B Biointerface. 2024;237**:**113837.
25. Kral Ö, Ilbasmis-Tamer S, Han S, Yücel Ç, Tirnaksiz F, Aygün B, Sola V, Cinan E. Development of nanosuspension-based thermosensitive gel formulation for radiodermatitis treatment: In vitro-in vivo characterization and investigation of neutron-gamma absorption properties. J Drug Deliv Sci Technol. 2025;110**:**107048.
26. Kulkarni R, Fanse S, Lalla RV, Morales D, Burgess DJ. Mucoadhesive in situ forming Gels: Bridging Formulation design and physiological Realities. Int J Pharm. 2025;681**:**125834.
27. Romanhole RC, Fava ALM, Tundisi LL, Macedo LMD, Santos ÉMD, Ataide JA, Mazzola PG. Unplanned absorption of sunscreen ingredients: Impact of formulation and evaluation methods. Int J Pharm. 2020;591**:**120013.
28. Sohn M, Herzog B, Osterwalder U, Imanidis G. Calculation of the sun protection factor of sunscreens with different vehicles using measured film thickness distribution — Comparison with the SPF in vitro. J Photochem Photobiol B Biol. 2016;159**:**74-81.