

**FORMULATION AND SPF EVALUATION OF SUNSCREEN GEL CONTAINING
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ABSTRACT

Background: Ultraviolet (UV) radiation contributes to skin damage and premature aging. *Murraya koenigii* leaves contain bioactive compounds with antioxidant and anti-inflammatory properties that may provide photoprotective effects. This study aimed to formulate *Murraya koenigii* leaf extract into sunscreen gels and evaluate their physical characteristics and in vitro sun protection factor (SPF). **Methodology:** *Murraya koenigii* leaves were extracted by maceration using 90% ethanol. The resulting extract was incorporated into sunscreen gel formulations at concentrations of 0%, 1%, 3%, and 9% (F0–F3). The formulations were evaluated for organoleptic characteristics, homogeneity, pH, viscosity, spreadability, adhesiveness, and in vitro SPF. Data were analyzed using IBM SPSS Statistics. Normality and homogeneity were assessed using the Shapiro–Wilk and Levene’s tests, respectively. Normally distributed and homogeneous data were analyzed using one-way analysis of variance followed by Tukey’s post hoc test, while non-normally distributed data were analyzed using the Kruskal–Wallis test. **Results:** All formulations showed homogeneous characteristics with acceptable physical appearance. The pH values ranged from 5.20 ± 0.02 to 6.38 ± 0.02 , while viscosity increased from $30,562 \pm 18.46$ cP in F0 to $39,854 \pm 16.11$ cP in F3. Increasing extract concentration was associated with decreased spreadability and increased adhesiveness. The in vitro SPF values increased progressively with extract concentration, from 1.83 ± 0.08 in F0 to 9.54 ± 0.09 , 15.92 ± 0.04 , and 18.77 ± 0.16 in F1, F2, and F3, respectively. **Conclusion:** *Murraya koenigii* leaf extract can be successfully incorporated into sunscreen gel formulations. The 9% extract formulation (F3) exhibited the highest in vitro SPF and demonstrated promising potential as a natural active ingredient for sunscreen gel preparations.

KEYWORDS: *Murraya koenigii*; leaf extract; sunscreen gel; sun protection factor; SPF; topical formulation.**1. INTRODUCTION**

Ultraviolet (UV) radiation is an important environmental factor that can adversely affect the skin, particularly following excessive or prolonged exposure. UV radiation can induce oxidative stress and inflammatory responses, which may contribute to erythema, premature skin aging, cellular damage, and other forms of photo-induced skin injury (Papaccio et al., 2022). Sunscreen preparations are therefore widely used to reduce the harmful effects of UV radiation by absorbing, reflecting, or scattering UV radiation before it reaches the skin. Although synthetic UV filters are commonly incorporated into sunscreen products, the increasing interest in naturally derived ingredients has encouraged the investigation of medicinal plants as potential sources of photoprotective compounds (Pizano-Andrade et al., 2022).

Natural products containing phenolic compounds and flavonoids are of particular interest because these compounds may provide antioxidant activity and contribute to protection against UV-induced oxidative stress (Kusmita et al., 2026). The presence of chromophoric structures in some plant-derived secondary metabolites may also contribute to their ability to absorb UV radiation. Consequently, plant extracts with antioxidant and UV-absorbing properties have been investigated as potential active ingredients for topical photoprotective preparations. The incorporation of such extracts into suitable pharmaceutical or cosmetic dosage forms may provide an alternative approach for developing plant-based sunscreen products (Li et al., 2023).

M. koenigii commonly known as curry leaf, belongs to the family Rutaceae and has been widely investigated for its pharmacological and phytochemical properties (Franyoto et al., 2025a). Its leaves contain various secondary metabolites, including phenolic compounds, flavonoids, carbazole alkaloids, and other constituents with reported biological activities (Singh et al., 2023). Previous studies have demonstrated antioxidant and anti-inflammatory activities of *M. koenigii* leaf extracts, suggesting that the plant may have potential for topical applications (Yohanes et al., 2023). The antioxidant properties of its constituents are particularly relevant to photoprotection because oxidative stress is one of the important mechanisms involved in UV-induced skin damage (Zhao et al., 2025).

The development of a topical gel containing *M. koenigii* leaf extract may provide a practical approach for utilizing these biological properties in a photoprotective preparation (Franyoto et al., 2026). Gel formulations are commonly used for topical application because of their ease of spreading, relatively non-greasy characteristics, and ability to provide uniform contact between the active ingredient and the skin surface (Dan et al., 2024). However, incorporation of a plant extract into a gel does not necessarily guarantee adequate photoprotective activity. Therefore, the resulting formulation must be evaluated for both its physicochemical characteristics and its ability to provide protection against UV radiation.

One of the commonly used preliminary approaches for evaluating sunscreen activity is the determination of the sun protection factor (SPF) by UV-Visible spectrophotometry (Agarkar et al., 2024). The in vitro SPF value provides an estimate of the photoprotective potential of a preparation based on its UV absorption characteristics. The Mansur spectrophotometric method calculates SPF from absorbance measurements within the UVB wavelength range, generally from 290 to 320 nm (Lefahal et al., 2018). This approach has been widely applied for preliminary screening of sunscreen formulations and plant extracts. Nevertheless, in vitro SPF determination should be interpreted as an initial assessment of photoprotective potential rather than as a substitute for standardized in vivo SPF testing.

Although the phytochemical composition and biological activities of *M. koenigii* have been extensively investigated, further research is required to evaluate its potential as an active ingredient in a specifically designed sunscreen gel. In particular, the relationship between incorporation of *M. koenigii* leaf extract into a gel formulation, the resulting physicochemical properties, and the in vitro SPF value requires further investigation. Therefore, this study aimed to formulate a sunscreen gel containing *M. koenigii* leaf extract and evaluate its physicochemical characteristics and in vitro SPF. The study provides preliminary evidence for the potential utilization of *M. koenigii* leaf extract as a plant-

derived ingredient in topical photoprotective preparations.

2. MATERIAL AND METHODS

2.1 Material

Dried leaves of *M. koenigii* were used as the plant material. Carbopol® 940 (Lubrizol, USA), propylene glycol, glycerin, methyl paraben, propyl paraben, triethanolamine, ethanol, and distilled water were used for the preparation of the gel formulations. Ethanol was also used for sample preparation in the in vitro SPF assay. Analytical-grade reagents were used throughout the study.

2.2 Preparation of *M. Koenigii* Extract

Leaves of *M. koenigii* were dried, pulverized, and subjected to extraction using 90% ethanol as the extraction solvent. A total of 1,500 g of powdered plant material was macerated at room temperature. Prior to extraction, the botanical identity of the plant material was confirmed, and a voucher specimen was deposited under the reference number 45.25.9/UNI/FFA.2/BF/PT/2023. The extraction was carried out through three successive maceration cycles, each lasting 24 h, with periodic mixing during the extraction period to improve contact between the plant material and solvent. Following each cycle, the liquid extract was separated from the plant residue, and all macerates were pooled. The combined extract was subsequently concentrated under reduced pressure using a rotary evaporator to obtain a viscous ethanolic extract. The extraction procedure produced a yield of 22.78%. The resulting extract was transferred into a tightly sealed container and maintained under suitable storage conditions until it was used for further formulation and analysis (Franyoto et al., 2025b).

2.3 Preparation of *M. koenigii* Leaf Extract Gel

The gel formulations were prepared using Carbopol 940 as the gelling agent. The required amount of Carbopol 940 was gradually dispersed in a portion of distilled water while stirring continuously to avoid the formation of lumps. The dispersion was allowed to hydrate until a uniform Carbopol dispersion was obtained.

Methyl paraben and propyl paraben were dissolved in propylene glycol with continuous stirring until a homogeneous solution was obtained. Glycerin was subsequently added to the mixture and mixed thoroughly. The preservative-propylene glycol mixture was then incorporated gradually into the hydrated Carbopol dispersion with continuous stirring until a uniform mixture was formed. For the extract-containing formulations, the predetermined amount of *M. koenigii* leaf extract was first mixed with a small portion of the remaining distilled water until adequately dispersed. The extract dispersion was then slowly incorporated into the Carbopol mixture while stirring continuously to ensure uniform distribution of the extract throughout the gel.

Triethanolamine was added dropwise with continuous stirring until the desired gel consistency and pH were obtained. The remaining distilled water was then added gradually to obtain a final volume of 100 mL. The formulations were mixed until a homogeneous gel was

obtained and subsequently allowed to stand to remove entrapped air bubbles. The prepared gels were transferred into tightly closed containers and stored at room temperature until further evaluation.

Table 1: Formulation of *M. koenigii* Leaf Extract Gel.

Ingredients	F0	F1	F2	F3
<i>M. koenigii</i> leaf extract	0%	1%	3%	9%
Carbopol 940	1%	1%	1%	1%
Propylene glycol	10%	10%	10%	10%
Methyl paraben	0.2%	0.2%	0.2%	0.2%
Propyl paraben	0.1%	0.1%	0.1%	0.1%
Glycerin	1%	1%	1%	1%
Triethanolamine	q.s.	q.s.	q.s.	q.s.
Distilled water	ad 100 mL	ad 100 mL	ad 100 mL	ad 100 mL

2.4 Physical Evaluation of Gel Formulations

The physical characteristics of the gel formulations were evaluated based on their organoleptic properties, homogeneity, pH, spreadability, adhesiveness, and viscosity. All evaluations were performed after the formulations had been prepared and equilibrated at room temperature.

2.4.1 Organoleptic Properties

The organoleptic characteristics of the formulations were evaluated by visual and sensory observation. The appearance, color, odor, and consistency of each gel formulation were recorded. The observations were used to identify any apparent differences among formulations and to detect visible changes in their physical characteristics.

2.4.2 Homogeneity

Homogeneity was assessed by placing a small amount of each gel formulation onto a clean glass slide and spreading it evenly to obtain a thin layer. The sample was then examined visually for the presence of coarse particles, aggregates, lumps, or other non-uniform components. A formulation was considered homogeneous when no visible particles or aggregates were observed and the color and texture appeared uniformly distributed throughout the sample.

2.4.3 pH

The pH of the gel formulations was determined using a calibrated digital pH meter. Prior to measurement, the instrument was calibrated using standard buffer solutions at pH 4.0 and 7.0. Approximately 1 g of gel was dispersed in 10 mL of distilled water and mixed thoroughly until a uniform dispersion was obtained. The electrode was immersed in the sample, and the pH value was recorded after the reading had stabilized. The measurement was performed to assess the suitability of the formulations for topical application. A pH range of 4.5–8.0 was used as the acceptable reference range for topical preparations.

2.4.4 Spreadability

The spreadability of the gel was evaluated using the glass plate method. Briefly, 1 g of gel was placed at the center of a glass plate measuring 20 × 20 cm and covered with a second glass plate. A load was subsequently applied until the total weight reached 100 g. After 1 min, the diameter of the spread gel was measured in several directions, and the mean value was calculated. The spreadability results were expressed in centimeters (cm), with a target range of approximately 5–7 cm.

2.4.5 Adhesiveness

The adhesive property of the gel was determined by measuring the time required for separation between two glass slides containing the gel sample. Approximately 0.25 g of gel was placed between two glass slides and compressed with a 1 kg load for 5 min. After removal of the load, the slides were mounted on the adhesion-testing apparatus and subjected to an additional 80 g load. The time required for complete separation of the two slides was recorded in seconds. Higher adhesion time indicated stronger adhesive properties of the formulation.

2.4.6 Viscosity

The viscosity of the gel formulations was determined using a Brookfield rotational viscometer equipped with spindle No. 64. Approximately 100 mL of the formulation was transferred into a suitable cylindrical container, and the spindle was immersed in the sample without contacting the container walls or bottom. The measurement was performed at a rotational speed of 30 rpm. After the reading stabilized, the displayed value was recorded and converted to centipoise (cP) using the appropriate instrument conversion factor. The viscosity was reported as cP and used to evaluate the consistency and flow characteristics of the gel formulations.

2.5 In Vitro Sun Protection Factor (SPF) Determination

The photoprotective activity of the gel formulations containing *M. koenigii* leaf extract was evaluated by determining the in vitro Sun Protection Factor (SPF) using UV-Visible spectrophotometry (da S. Almeida et

al., 2019). Each gel formulation was accurately weighed at 0.1 g and transferred into a 5 mL volumetric flask containing 96% ethanol. The sample was diluted to volume with the same solvent and mixed thoroughly to obtain a homogeneous solution. The absorbance of each sample was measured using a UV-Visible spectrophotometer over the UV-B wavelength range of 290–320 nm at 5 nm intervals. A solution of 96% ethanol was used as the blank. The absorbance values obtained at each wavelength were recorded and used for SPF calculation. Each formulation was evaluated under the same measurement conditions to ensure comparability among the different extract concentrations.

The SPF value was calculated using the Mansur spectrophotometric method, which estimates the photoprotective capacity of a sample based on its UV-B absorbance profile. The SPF value was calculated according to the following equation 1.

$$SPF = CF \times \sum_{290}^{320} EE(\lambda) \times I(\lambda) \times Abs(\lambda) \quad (1)$$

where CF is the correction factor, $EE(\lambda)$ represents the erythral effect spectrum at wavelength λ , $I(\lambda)$ denotes the solar intensity spectrum, and $Abs(\lambda)$ is the measured absorbance of the sample at the corresponding wavelength. The resulting SPF values were used to compare the photoprotective potential of the different gel formulations.

2.6 Statistical Analysis

All quantitative data were expressed as mean $\pm$ standard deviation (SD). Statistical analysis was performed using IBM SPSS Statistics [version]. Data normality was assessed using the Shapiro–Wilk test, while homogeneity of variances was evaluated using Levene's test. For data that were normally distributed and showed homogeneous variances, differences among the four formulations (F0–F3) were analyzed using one-way analysis of variance (ANOVA), followed by Tukey's honestly significant difference (HSD) test for multiple comparisons. For data that did not meet the assumptions of normality and/or homogeneity, the Kruskal–Wallis test was applied. When the Kruskal–Wallis test showed a significant difference, an appropriate post hoc multiple-comparison test was performed. A P value < 0.05 was considered statistically significant.

3. RESULTS AND DISCUSSION

3.1 Organoleptic Characteristics and Homogeneity

The organoleptic evaluation was conducted to characterize the physical appearance of the formulated *M. koenigii* leaf extract sunscreen gels. The evaluated parameters included dosage form, color, odor, and texture. Homogeneity was assessed by observing the formulations for the presence of visible aggregates, coarse particles, or non-uniform areas. The results of the organoleptic and homogeneity evaluations are presented in Table 2.

Table 2: Organoleptic characteristics and homogeneity of *M. koenigii* leaf extract sunscreen gel formulations

Evaluation parameter	F0 (0%)	F1 (1%)	F2 (3%)	F3 (9%)
Color	White	Light green	Green	Dark green
Odor	Odorless	Odorless	Odorless	Odorless
Texture	Slightly thick	Less thick	Slightly thick	Slightly thick
Homogeneity	Homogeneous	Homogeneous	Homogeneous	Homogeneous

The organoleptic evaluation showed that all formulations produced semisolid gel preparations with acceptable physical appearances. The color gradually changed from white in F0 to light green, green, and dark green in F1, F2, and F3, respectively, corresponding to the increasing concentration of *M. koenigii* leaf extract. This color variation may be attributed to the naturally occurring pigments and other colored constituents present in the extract. All formulations were odorless and exhibited suitable gel consistency.

All formulations demonstrated good homogeneity, with no visible aggregates, coarse particles, or non-uniform regions. This indicates that the *M. koenigii* leaf extract was adequately incorporated and uniformly distributed within the Carbopol 940 gel matrix (Samir & Barhate, 2024). The absence of visible phase separation further indicates that the formulation process produced physically uniform gel preparations at all tested extract concentrations.

3.2 pH

The pH values of the sunscreen gel formulations ranged from 5.20 ± 0.02 to 6.38 ± 0.02 (Figure 1). A gradual decrease in pH was observed with increasing concentrations of *M. koenigii* leaf extract, from 6.38 in F0 to 5.20 in F3. This decrease may be associated with the presence of acidic phytoconstituents in the plant extract (Akhter et al., 2024). Nevertheless, all formulations remained within the generally acceptable pH range for topical preparations (4.5–6.5), indicating their suitability for topical application (Bayan et al., 2023).

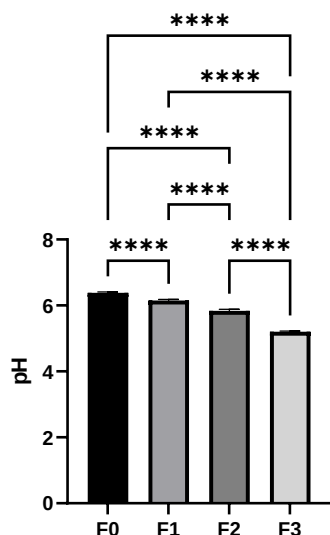


Fig. 1: pH values of *Murraya koenigii* leaf extract sunscreen gel formulations.

*Data are presented as mean ± S.D. of three experiments. Statistical significance was determined by pairwise comparison; **** $P < 0.0001$.

Statistical analysis demonstrated significant differences in pH among the sunscreen gel formulations containing different concentrations of *M. koenigii* leaf extract (Figure 1). Pairwise comparisons showed significant differences between F0 and F1 ($p < 0.001$), while the comparisons between F0 and F2, F0 and F3, F1 and F2, F1 and F3, and F2 and F3 were highly significant ($p < 0.0001$). These findings were consistent with the descriptive results, which showed a progressive decrease in pH from 6.38 ± 0.02 in F0 to 6.15 ± 0.03 , 5.84 ± 0.04 , and 5.20 ± 0.02 in F1, F2, and F3, respectively.

The progressive decrease in pH observed with increasing concentrations of *M. koenigii* leaf extract may be associated with the contribution of acidic constituents and other ionizable phytochemicals present in the extract. Previous studies have demonstrated that incorporation of botanical extracts into topical gel systems can alter the pH of the formulation, depending on the phytochemical composition of the extract and its interaction with the formulation matrix (Şentürk et al., 2025). *M. koenigii* leaves contain diverse phytoconstituents, including phenolic compounds and flavonoids, which may contribute to changes in the proton balance of the formulation (Perera et al., 2023). Despite the statistically significant differences, all formulations remained within the acceptable pH range of 4.5–6.5 for topical preparations. This finding indicates that incorporation of *M. koenigii* leaf extract at concentrations up to 9% resulted in a measurable alteration in pH while maintaining physicochemical compatibility with topical application.

3.3 Spreadability

The spreadability of the sunscreen gel formulations was evaluated and the results are presented in Figure 2. The mean spreadability decreased progressively with increasing concentration of *M. koenigii* leaf extract. The F0 formulation, containing no extract, exhibited the highest spreading diameter of 5.875 ± 0.15 cm. The addition of *M. koenigii* extract reduced the spreadability to 4.775 ± 0.19 cm in F1 (1%), 4.10 ± 0.07 cm in F2 (3%), and 3.63 ± 0.11 cm in F3 (9%).

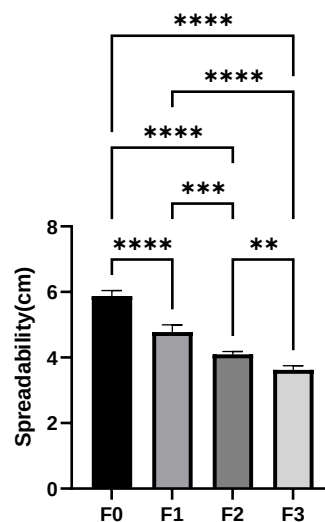


Fig. 2: Spreadability of *M. koenigii* leaf extract sunscreen gel formulations.

*Data are presented as mean ± S.D. of three experiments. Statistical significance was determined by one-way ANOVA followed by Tukey's post hoc test; ** $P < 0.01$; *** $P < 0.001$; **** $P < 0.0001$.

The decrease in spreadability may be associated with the increasing viscosity of the formulations following the incorporation of *M. koenigii* leaf extract. As observed in the viscosity evaluation, the viscosity increased from $30,562 \pm 18.46$ cP in F0 to $39,854 \pm 16.11$ cP in F3. A more viscous gel generally exhibits greater resistance to deformation and flow, resulting in a smaller spreading diameter under the same applied load. Therefore, the lower spreadability observed at higher extract concentrations is consistent with the viscosity profile of the formulations (Volk & Stopar, 2026). The reduction in spreadability may also be related to interactions between extract constituents and the Carbopol 940 polymer network. Increasing the amount of extract may alter the structure and intermolecular interactions within the gel matrix, resulting in increased resistance to flow. Nevertheless, all formulations remained capable of spreading under the applied load, indicating that incorporation of *M. koenigii* leaf extract up to 9% did not prevent the gel from being distributed over a surface.

The relatively low standard deviation values (0.07–0.19 cm) indicate good repeatability of the spreadability measurements. Overall, the results demonstrate an

inverse relationship between extract concentration and spreadability, which is accompanied by an increase in viscosity (Waqas et al., 2022). F0 showed the greatest spreadability, whereas F3 exhibited the lowest spreadability, suggesting that the 9% extract formulation produces a more viscous and comparatively less easily spread gel.

3.4 Adhesiveness

The adhesiveness of the sunscreen gel formulations increased progressively with increasing concentrations of *M. koenigii* leaf extract (Figure 3). The mean adhesion time increased from 0.46 ± 0.04 s in F0 to 0.71 ± 0.07 s in F1 (1%), 0.92 ± 0.04 s in F2 (3%), and 1.12 ± 0.06 s in F3 (9%). This progressive increase indicates that the incorporation of *M. koenigii* leaf extract enhanced the ability of the gel to remain in contact with the test surface.

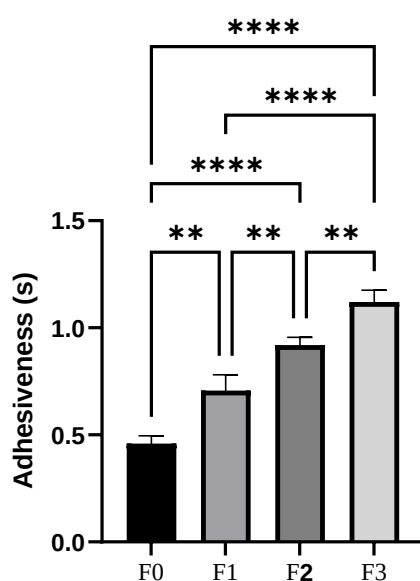


Fig. 3. Effect of different concentrations of *M. koenigii* leaf extract (0%, 1%, 3%, and 9%) on the adhesiveness of sunscreen gel formulations.

*Data are presented as mean $\pm$ S.D. of three experiments. Statistical significance was determined by one-way ANOVA followed by Tukey's post hoc test; ** $P < 0.01$; **** $P < 0.0001$.

Statistical analysis confirmed significant differences in adhesiveness among the formulations. Pairwise comparisons showed significant differences between F0 and F1, F1 and F2, and F2 and F3 ($p < 0.01$), whereas comparisons between F0 and F2, F0 and F3, and F1 and F3 showed highly significant differences ($p < 0.0001$). The increase in adhesiveness was consistent with the viscosity results, which increased from $30,562 \pm 18.46$ cP in F0 to $39,854 \pm 16.11$ cP in F3. Higher viscosity increases resistance to flow and separation from the applied surface, thereby contributing to longer adhesion time. In addition, the increasing concentration of *M. koenigii* extract may influence interactions within the

Carbopol 940 polymer matrix, resulting in increased resistance to separation. The relatively low standard deviation values (0.04 – 0.07 s) indicate good repeatability of the measurements. Overall, the results demonstrate that increasing *M. koenigii* leaf extract concentration significantly enhanced the adhesiveness of the sunscreen gel, with F3 exhibiting the highest adhesion time (1.12 ± 0.06 s). This increased adhesiveness may improve retention of the preparation on the skin, although it should be considered together with spreadability and viscosity when selecting the optimum formulation (Al-Barghouthy et al., 2025).

3.5 Viscosity

The viscosity of the sunscreen gel formulations increased progressively with increasing concentrations of *M. koenigii* leaf extract (Figure 4). The mean viscosity increased from $30,562 \pm 18.46$ cP for F0 to $36,246 \pm 15.63$ cP, $38,201 \pm 10.66$ cP, and $39,854 \pm 16.11$ cP for F1, F2, and F3, respectively. The increase in viscosity may be attributed, at least in part, to potential interactions between phytoconstituents present in the *M. koenigii* leaf extract and the Carbopol 940 polymer network, which may increase the internal resistance to flow at higher extract concentrations.

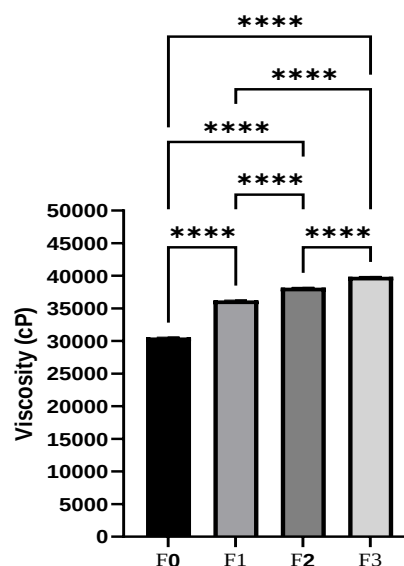


Fig. 4: Effect of *M. koenigii* leaf extract concentration on the viscosity of sunscreen gel formulations.

*Data are presented as mean $\pm$ S.D. of three experiments. Statistical significance was determined by pairwise comparison; **** $P < 0.001$; **** $P < 0.0001$.

The relatively small standard deviation values indicate low variability among the three replicate measurements for each formulation, reflecting good consistency of the viscosity measurements. The increase in viscosity should also be considered in relation to the spreadability and physical stability of the gel, as excessive viscosity may impair ease of application and reduce spreadability, whereas insufficient viscosity may compromise the ability of the formulation to maintain adequate

consistency and remain uniformly distributed on the skin. Therefore, an appropriate balance between viscosity, spreadability, and physical stability is essential when selecting the optimum sunscreen gel formulation (Al-Barghouthy et al., 2025).

3.6 In Vitro SPF

The in vitro SPF evaluation showed a clear increase in photoprotective activity with increasing concentrations

of *M. koenigii* leaf extract (Table 3). The control formulation (F0) exhibited a low SPF value of 1.83 ± 0.08 , indicating no meaningful photoprotective potential. In contrast, incorporation of 1% extract in F1 markedly increased the SPF to 9.54 ± 0.09 , categorized as having maximum photoprotective potential.

Table 3: In vitro SPF values of *M. koenigii* leaf extract sunscreen gel formulations.

Formulation	SPF Value (Mean $\pm$ SD)	Photoprotective Potential
F0 (0%)	1.83 ± 0.08	No potential
F1 (1%)	9.54 ± 0.09	Maximum
F2 (3%)	15.92 ± 0.04	Ultra
F3 (9%)	18.77 ± 0.16	Ultra

The progressive increase in SPF suggests that the photoprotective activity of the gel was primarily associated with the presence and increasing concentration of *M. koenigii* leaf extract. This effect may be attributed to phenolic and flavonoid constituents present in the extract, which can absorb ultraviolet radiation, particularly in the UVB region, thereby contributing to the observed SPF (Li et al., 2023). Overall, the results demonstrate a concentration-dependent enhancement of in vitro SPF, with F3 showing the highest SPF value (18.77 ± 0.16). However, these values represent in vitro photoprotective activity based on spectrophotometric measurement and should not be interpreted as equivalent to clinical or in vivo SPF protection.

4. CONCLUSION

The *M. koenigii* leaf extract was successfully formulated into sunscreen gel preparations with acceptable organoleptic characteristics, homogeneity, pH, viscosity, spreadability, and adhesiveness. Increasing the extract concentration resulted in increased viscosity and adhesiveness, accompanied by a decrease in spreadability. The in vitro SPF value increased progressively with increasing extract concentration, with F3 containing 9% *M. koenigii* leaf extract exhibiting the highest SPF value (18.77 ± 0.16), followed by F2 (15.92 ± 0.04) and F1 (9.54 ± 0.09). These findings indicate that *M. koenigii* leaf extract has potential as a natural active ingredient in topical sunscreen gel formulations, particularly at the 9% concentration.

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Competing interests

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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