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Formulation and In Vitro SPF Determination of *Aloe vera* Gel Lip Balm

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ABSTRACT

Background: *The lips are highly sensitive to environmental exposure and require protection to maintain moisture. Lip balms containing SPF provide both moisturizing effects and protection against sun-induced damage. The photoprotective potential of Aloe vera may be related to its bioactive constituents, such as flavonoids and lignin, as reported in previous studies.*

Objective: *This study aimed to formulate Aloe vera gel lip balm and evaluate their SPF values.*

Methods: *Aloe vera gel lip balm formulations were prepared at different concentrations (0%, 30%, 35%, and 40%), followed by physical quality tests covering organoleptic properties, homogeneity, pH, melting point, and spreadability, and continued with SPF value determination. For SPF determination, 0.5 g of each formulation was dissolved in n-hexane and analyzed using a UV–Vis spectrophotometer at 290–320 nm at 5 nm intervals, with n-hexane as the blank. Each formulation was subjected to three analytical measurements. SPF values were calculated using the Mansur method. Data were analyzed using one-way ANOVA followed by post-hoc test at a 95% confidence level.*

Results: *The results of the physical quality evaluation showed that all lip balm formulations containing 0%, 30%, 35%, and 40% Aloe vera gel met the established physical quality standards for organoleptic properties, homogeneity, pH, melting point, and spreadability. The SPF value of the lip balm with 0% Aloe vera gel was 3.078 ± 0.013, indicating minimal protection. The 30%, 35%, and 40% concentrations had SPF values of 19.238 ± 0.145, 20.672 ± 0.522, and 22.399 ± 0.111, respectively, indicating moderate protection.*

Conclusion: *The Aloe vera-containing formulations (F1–F3) demonstrated higher in vitro estimated SPF values than the base formulation (F0). Among the Aloe vera-containing formulations, F3 with 40% Aloe vera gel showed the highest estimated SPF value. These findings indicate a potential concentration-dependent increase in the in vitro estimated SPF of the lip balm formulations.*

Keywords: **Aloe vera gel; *Aloe vera L.*; *Lip balm*; SPF**

Introduction

Lips are a prominent facial feature that significantly influence facial aesthetics. Compared with other areas of facial skin, the lips have relatively limited protective structures and are susceptible to environmental exposure (Setiawan et al., 2022). Sun exposure, particularly ultraviolet (UV) radiation, is an important environmental factor that may adversely affect the lips, contributing to dryness, chapping, inflammation, and discomfort (Suleman et al., 2022). At the global level, excessive UV radiation is an important public health concern. In 2020, more than 1.5 million cases of skin cancer and more than 120,000 associated deaths were reported worldwide. The World Health Organization (WHO) recommends sun-protection measures when the UV Index reaches 3 or higher.

Indonesia, as a tropical country, experiences substantial solar radiation throughout the year. According to the Indonesian Meteorology, Climatology, and Geophysical Agency (BMKG), the UV Index in Indonesia generally increases from low levels in the morning and may reach the high, very high, or extreme categories during the period of highest solar radiation, particularly around 12:00–15:00 local time. The level of UV exposure varies according to geographical location, elevation, solar position, surface characteristics, and cloud cover. In East Java, BMKG has reported that the UV Index can already reach the low-to-moderate risk category at approximately 08:00 WIB, indicating that UV exposure occurs from the morning and increases toward midday. At the local study setting in Jember, measurements conducted at Politeknik Negeri Jember reported an average solar irradiance of approximately 4.4 kWh/m^2/day, demonstrating substantial solar energy exposure in the area. These conditions highlight the relevance of developing topical

preparations that can help protect exposed areas, including the lips, from the potential effects of UV radiation.

Therefore, maintaining lip moisture and providing protection against environmental exposure are important. Lip balm is a topical cosmetic preparation commonly used to prevent dry lips by maintaining moisture and providing a protective layer against environmental factors. Lip balms generally contain fats, waxes, oils, and other functional ingredients (Setiawan et al., 2022). The incorporation of natural ingredients into lip balm formulations may provide additional functional benefits. One natural ingredient with potential for topical application is *Aloe vera*.

Aloe vera has been widely investigated for its moisturizing and biological properties and contains various bioactive constituents, including flavonoids, tannins, anthraquinones, and saponins (Gunarti et al., 2022). Previous studies have also reported lignin as one of the constituents of *Aloe vera*, which may facilitate the absorption of the gel into the skin and contribute to its moisturizing properties (Tampubolon, 2023). Flavonoids have also been reported to possess potential photoprotective properties through their ability to absorb UV radiation and through antioxidant activity (Li et al., 2023; Fujishiro et al., 2024). However, these proposed photoprotective effects are based on previous literature. The present study did not quantify lignin, flavonoids, aloin, or other marker compounds; therefore, their specific contribution to the SPF of the tested formulations cannot be confirmed.

The Sun Protection Factor (SPF) is an indicator used to estimate the photoprotective capacity of a preparation against UV radiation (Risnayanti et al., 2022). Previous research reported that an *Aloe vera* gel sunscreen lotion containing 20% *Aloe vera* showed an SPF value of 10.21 (Hendrawati et al., 2020). In addition, an *Aloe vera*-containing lip balm formulation has previously been reported to demonstrate good physical stability (Zuhriah et al., 2021). These findings indicate the potential of *Aloe vera* for use in topical and lip balm preparations. However, the available evidence does not sufficiently clarify the effect of increasing *Aloe vera* gel concentrations on the in vitro estimated SPF of a lip balm dosage form. In particular, the relationship between progressively increased *Aloe vera* gel concentrations and the resulting SPF values in a lip balm formulation remains insufficiently characterized.

In the present study, *Aloe vera* gel concentrations of 30%, 35%, and 40% were selected to provide a progressive 5% increase in the concentration of *Aloe vera* and to evaluate whether increasing concentrations were associated with higher in vitro estimated SPF values. The selected concentrations also extend the concentration range beyond the previously reported 20% *Aloe vera* sunscreen formulation (Hendrawati et al., 2020), while investigating *Aloe vera* in a different dosage form, namely lip balm. The novelty of this study lies in the systematic evaluation of different *Aloe vera* gel concentrations in a lip balm formulation and the determination of their in vitro estimated SPF values using UV–Vis spectrophotometry and the Mansur method. Therefore, this study aimed to formulate *Aloe vera* gel lip balm preparations containing 30%, 35%, and 40% *Aloe vera* gel and to evaluate their physical characteristics and in vitro estimated SPF values.

Methods

Study Design

A laboratory-based experimental study was conducted to evaluate the effect of varying concentrations of *Aloe vera* gel in lip balm formulations on their physical characteristics and in vitro estimated SPF values. Four formulations (F0–F3) were prepared, with three independent formulation batches prepared for each formulation. Each batch was considered an independent experimental unit.

Setting

The study was conducted in April 2025. Botanical identification and authentication of *Aloe vera* were carried out at the UPT Herbal Materia Medica Laboratory, Batu, Malang, Indonesia, on 15 April 2025. The plant material was authenticated as *Aloe vera* (L.) Burm.f. under identification number 000.9.3/1266/102.20/2025. The formulation, physical quality evaluation, and in vitro

SPF determination of the lip balm preparations were conducted at the Laboratory of Harapan Bangsa College of Health Sciences.

Instruments

The equipment used in this study included an analytical balance (Shimadzu), blender (Philips), water bath (Memmert), measuring cup (Pyrex), beaker (Pyrex), oven (Memmert), microscope slide (Onemed), pH meter (Ohaus), and UV–Vis spectrophotometer (Shimadzu).

Materials

The materials used in this study included *Aloe vera* gel, VCO (HIU), cetyl alcohol (Merck), cera alba (Sigma-Aldrich), propylene glycol (Merck), white petrolatum (Sigma-Aldrich), *n*-hexane (Merck), and distilled water (Onemed).

Intervention

Preparation of Aloe vera Gel

Fresh *Aloe vera* leaves were obtained from Pontang Village, Ambulu District, Jember Regency. Mature, healthy, and undamaged leaves of relatively uniform size were selected. The leaves were processed on the same day of harvesting to minimize changes in the fresh gel. The leaves were washed thoroughly with running water, and the outer rind was carefully removed together with the visible yellow latex/exudate beneath the rind. The inner gel was then scooped out using a clean spoon, blended without the addition of water, and filtered to remove fibrous material (Mujiono & Ismedsyah, 2020). The freshly prepared gel was used directly for formulation.

Lip balm Preparation

Lip balm formulations were prepared according to the compositions presented in Table 1. Each formulation (F0–F3) were prepared, with a total batch size of 100 g per batch. Cetyl alcohol and cera alba were placed in a porcelain dish and heated in a water bath at 70°C until completely melted. White petrolatum and VCO were then gradually added and mixed until a homogeneous lipid phase was obtained. The mixture was removed from the water bath and allowed to cool to approximately 40°C, after which propylene glycol and freshly prepared Aloe vera gel were gradually incorporated while continuously stirring at 500 rpm for 10 min. The resulting preparation was poured into 10 g containers, allowed to cool at room temperature (25 ± 2°C) until set, and subsequently refrigerated at 4°C for 1 h to facilitate complete solidification. The prepared formulations were then stored in closed containers at room temperature (25 ± 2°C) until evaluation.

Table 1. Composition of *Aloe vera* Gel Lip Balm Formulations

Ingredient	Function	Formula (%)			
		F0	F1	F2	F3
Aloe vera gel	Active ingredient	0	30	35	40
VCO	Emollient	17,5	17,5	17,5	17,5
Propylene glycol	Humectant	2	2	2	2
Cetyl alcohol	Co-emulsifier	3	3	3	3
Cera alba	Base	10	10	10	10
White petrolatum	Base	67.5	37.5	32.5	27.5
Total		100	100	100	100

Physic Evaluation of Lip balm

Organoleptic Test

This test involves visually observing the lip balm preparation, including its color, texture, and aroma (Agustiana et al., 2019). Organoleptic testing is intended to identify changes that may occur after the formulation process (Suleman et al., 2022).

Homogeneity Test

A total of 1 gram of lip balm was weighed and spread evenly on a microscope slide. The sample was visually examined for homogeneity. The preparation was considered homogeneous if no coarse particles or lumps were observed (Yusuf et al., 2019).

pH Measurement

The pH of the lip balm formulations was determined using a 1% (w/v) aqueous dispersion. Briefly, 1 g of lip balm was dispersed in distilled water and the volume was adjusted to 100 mL. The dispersion was gently heated until a uniform dispersion was obtained and then allowed to cool to room temperature (25 ± 2°C) before measurement. A calibrated pH meter was used for the measurement. The pH meter was calibrated using standard buffer solutions of pH 4.00 and 7.00 at the measurement temperature. The pH of each formulation was measured in triplicate, and the stabilized reading was recorded as the pH of the aqueous dispersion (Amanda and Zuhrotun., 2017).

Melting Point Measurement

A total of 1 g of lip balm was weighed and placed in a porcelain dish. The sample was heated in an oven at 50°C for 15 min. If the sample did not melt, the temperature was increased by 1°C at 15-min intervals until the defined melting endpoint was reached. The melting point was defined as the temperature at which the lip balm completely melted and no solid material remained visible. The determination was performed in triplicate from each formulation (F0–F3), and the results were expressed as mean ± standard deviation (SD) Ambari et al., 2020).

Spreadability Test

The spreadability test was performed by weighing 1 g of lip balm and placing the sample at the center of a circular glass plate with a diameter of 60 cm. The sample was covered with a second glass plate of the same dimensions, and a load of 200 g was applied for 1 min. The diameter of the spread sample was then measured in a single direction. The test was performed in triplicate, and the results were expressed as mean ± standard deviation (SD) (Risnayanti et al., 2022).

SPF Value Measurement

A total of 0.5 g of lip balm was weighed and transferred into a 10 mL volumetric flask, resulting in a nominal sample concentration of 50 mg/mL. The sample was dispersed in *n*-hexane, and the volume was adjusted to 10 mL. The mixture was thoroughly mixed until a uniform preparation was obtained and visually inspected to ensure the absence of visible undissolved particles or turbidity before UV–Vis measurement. *n*-Hexane was used as the blank. No further dilution was performed before measurement. The absorbance was measured at wavelengths ranging from 290 to 320 nm at 5-nm intervals using a UV–Vis spectrophotometer. Each formulation was measured in triplicate. The absorbance values obtained at each wavelength were recorded and used to calculate the in vitro estimated SPF according to the Mansur method (Endriyatno et al., 2024).

The in vitro estimated SPF was calculated using the Mansur method according to the following equation:

$$SPF = CF\ x \sum_{290}^{320} EE\ (\lambda) x\ I\ (\lambda) x\ abs\ (\lambda)$$

where CF is the correction factor, EE(λ) is the erythemal effect spectrum, I(λ) is the solar intensity spectrum, and Abs(λ) is the measured absorbance at each wavelength. The EE × I weighting constants used at each wavelength were 0.0150, 0.0817, 0.2874, 0.3278, 0.1864, 0.0839, and 0.0180 for 290, 295, 300, 305, 310, 315, and 320 nm, respectively. A correction factor (CF) of 10 was used. Three independent SPF determinations were performed for each formulation, and the final SPF value was expressed as mean ± standard deviation (SD), calculated from the three independent determinations.

Data Analysis

Data were analyzed using SPSS Statistics. Three independent batches were evaluated for each formulation (F0–F3; n = 3). Data normality and homogeneity of variance were assessed using the Shapiro–Wilk and Levene's tests, respectively. One-way ANOVA was performed at a 95% confidence level, followed by Tukey's post-hoc test when significant differences were detected ($p < 0.05$). The F statistic, degrees of freedom, exact p-value, and effect size were reported.

Result

Organoleptic Test

The *Aloe vera* gel filtrate was subsequently formulated into a lip balm, followed by physical quality evaluation and determination of its SPF. Organoleptic evaluation was performed to assess the physical characteristics of the lip balm formulations, including color, odor, and texture. The results showed that all formulations containing 0%, 30%, 35%, and 40% *Aloe vera* gel exhibited similar organoleptic characteristics. All formulations (F0, F1, F2, and F3) appeared white, reflecting the combined appearance of the ingredients used in the formulation. Although *Aloe vera* gel is naturally pale green, its color became less noticeable after being mixed with the other ingredients, resulting in a white final product (Table 2).

Tabel 2. Organoleptic Evaluation of *Aloe vera* Gel Lip Balm Formulations

Homogeneity Test

The homogeneity test was performed to detect the presence of coarse particles that may result from incomplete mixing of the formulation components (Nastiti et al., 2023). The homogeneity test results showed that all *Aloe vera* gel lip balm formulations (F0, F1, F2, and F3) met the homogeneity acceptance criteria (Table 3).

Formulation	Organoleptic		
	Color	Odor	Texture
F0	White	Characteristic odor	Smooth
F1	White	Characteristic odor	Smooth
F2	White	Characteristic odor	Smooth
F3	White	Characteristic odor	Smooth

Table 3. Homogeneity Test Results of *Aloe vera* Gel Lip Balm Formulations

Formulation	Results
F0	Homogenous
F1	Homogenous
F2	Homogenous
F3	Homogenous

pH Measurement

The pH values of the lip balm formulations ranged from 4.8 ± 0.10 to 6.2 ± 0.10. F0 showed the highest pH value (6.2 ± 0.10), while F3 showed the lowest (4.8 ± 0.10). All formulations met the specified pH acceptance criteria (Table 4). One-way ANOVA showed a significant difference in pH among the formulations ($p < 0.05$). Tukey's post-hoc test showed that F0 differed significantly from F1, F2, and F3, while F1 and F2 did not differ significantly from each other. F3 also differed significantly from all other formulations.

Table 4. pH Values of *Aloe vera* Gel Lip Balm Formulations

Formulation	pH ± SD
F0	6.2 ± 0.10[a]
F1	5.3 ± 0.15[b]
F2	5.1 ± 0.10[b]
F3	4.8 ± 0.10[c]

Values are presented as mean ± SD (n = 3). Different superscript letters indicate significant differences between formulations based on Tukey's post-hoc test ($p < 0.05$).

Melting Point Measurement

Melting point determination was performed to evaluate the temperature at which the lip balm formulations began to melt. The melting point values ranged from 51 ± 1°C to 54 ± 1°C, with F0 showing the lowest value and F3 the highest. All formulations met the melting point requirements specified in SNI 16-4769-1998, which recommends a melting point range of 50–70°C (Table 5). One-way ANOVA showed a significant difference in melting point among the formulations ($p < 0.05$). Tukey's post-hoc test showed that F0 and F1 did not differ significantly from each other, while F2 did not differ significantly from F0, F1, or F3. F3 differed significantly from F0 and F1.

Table 5. Melting Point Values of *Aloe vera* Gel Lip Balm Formulations

Formulation	Melting Point (°C) ± SD
F0	51 ± 1[a]
F1	52 ± 1[a]
F2	53 ± 1[ab]
F3	54 ± 1[b]

Values are presented as mean ± SD (n = 3). Different superscript letters indicate significant differences between formulations based on Tukey's post-hoc test ($p < 0.05$).

Spreadability Test

The spreadability test was performed to evaluate the ability of the lip balm formulations to spread during application. According to Ambari et al. (2020), the acceptable spreadability range for lip balm formulations is 3–5 cm. The spreadability values ranged from 4.0 ± 0.1 cm to 4.6 ± 0.1 cm, indicating that all formulations met the specified acceptance criterion (Table 6). One-way ANOVA showed a significant difference in spreadability among the formulations ($p < 0.05$). Tukey's post-hoc test showed that F0 differed significantly from F1, F2, and F3. F1 did not differ significantly from F2 but differed significantly from F3, while F2 did not differ significantly from F3.

Table 6. Spreadability Values of *Aloe vera* Gel Lip Balm Formulations

Formulation	Spreadability (cm) ± SD
F0	4.0 ± 0.1[a]
F1	4.3 ± 0.1[b]

F2	4.5 ± 0.1[bc]
F3	4.6 ± 0.1[c]

Values are presented as mean ± SD (n = 3). Different superscript letters indicate significant differences between formulations based on Tukey's post-hoc test ($p < 0.05$).

SPF Value Measurement

The estimated in vitro SPF values of the formulations were determined using the Mansur spectrophotometric method. F0, which did not contain *Aloe vera* gel, showed an estimated SPF value of 3.078 ± 0.013, corresponding to minimal protection (SPF 2–<12). The incorporation of *Aloe vera* gel increased the estimated SPF values, with F1 (30%), F2 (35%), and F3 (40%) showing values of 19.238 ± 0.145, 20.672 ± 0.552, and 22.399 ± 0.111, respectively. These values corresponded to moderate protection (SPF 12–<30). F3 showed the highest estimated in vitro SPF value. One-way ANOVA showed a significant difference in SPF values among the formulations ($p < 0.05$). Tukey's post-hoc test confirmed that all formulation pairs differed significantly from each other ($p < 0.001$) (Table 7).

Table 7. SPF Values of *Aloe vera* Gel Lip Balm Formulations

Formulation	SPF Value ± SD	Protection Category
F0	3.078 ± 0.013[a]	Minimal
F1	19.238 ± 0.145[b]	Moderate
F2	20.672 ± 0.552[c]	Moderate
F3	22.399 ± 0.111[d]	Moderate

Values are presented as mean ± SD (n = 3). Different superscript letters indicate significant differences between formulations based on Tukey's post-hoc test ($p < 0.05$). SPF values were estimated using the Mansur spectrophotometric method. Protection categories were interpreted as SPF 2–<12 (minimal), SPF 12–<30 (moderate), and SPF ≥30 (high).

Discussion

A total of 800 g of *Aloe vera* leaves were peeled to obtain the gel, which was then blended without the addition of water. The blended gel was subsequently filtered to separate the liquid filtrate from the fibrous residue. This step was performed to prevent the incorporation of fiber into the formulation, as it could adversely affect the texture of the lip balm. From 437.81 g of *Aloe vera* gel, 323.76 g of Aloe vera gel filtrate was obtained, corresponding to a yield of 73.95%. This relatively high yield is consistent with the high water content of *Aloe vera* gel, which is approximately 98-99.5% (Nalimu et al., 2021). Therefore, the yield obtained indicates that the blending and filtration process was effective in recovering the liquid fraction of the gel without the need for additional solvents. All formulations (F0, F1, F2, and F3) exhibited a characteristic coconut odor due to the presence of VCO. All formulations also exhibited a smooth and soft texture, which can be attributed to the use of white petrolatum as one of the base components. White petrolatum functions as an occlusive base and emollient, contributing to the smooth texture of the lip balm and facilitating its application to the lips (Sholehah et al., 2022).

The homogeneity testing was performed to ensure that the active ingredient is uniformly distributed throughout the formulation, thereby promoting consistent performance. In addition, homogeneity testing confirms the absence of lumps or aggregates that could compromise the physical quality of the lip balm (Arisanty et al., 2022). The homogeneity test results showed that all *Aloe vera* gel lip balm formulations (F0, F1, F2, and F3) met the homogeneity acceptance criteria. This was indicated by the absence of coarse particles and the uniform appearance of each formulation. The homogeneous nature of the formulations can be attributed to the thorough mixing process during preparation, which ensured the uniform distribution of all formulation components (Ridhani & Nurul Hidayah, 2022).

The pH value is an important parameter in the evaluation of topical formulations because it influences the stability of the formulation and its active ingredients, as well as user comfort

during application. A pH that is too low (acidic) may cause skin irritation, whereas a pH that is too high (alkaline) may lead to dryness and scaling of the skin (Endriyatno et al., 2024). The acceptable pH range for lip balm formulations is 4.5–6.5, which corresponds to the natural pH of the lip surface (Ambari et al., 2020). All formulations exhibited pH values within this range, indicating that they met the acceptable pH criteria. However, a gradual decrease in pH was observed with increasing concentrations of *Aloe vera* gel. This trend can be attributed to the naturally acidic nature of *Aloe vera* gel, which has a pH of approximately 4.8 before formulation Sai et al. (2021). Consequently, increasing the concentration of *Aloe vera* gel resulted in lower pH values in the lip balm formulations. Furthermore, statistical analysis demonstrated that variations in the concentration of *Aloe vera* gel had a significant effect on the pH of the lip balm formulations.

The melting point of the lip balm formulations increased gradually with increasing *Aloe vera* gel concentration, from 51 ± 1°C in F0 to 52 ± 1°C in F1, 53 ± 1°C in F2, and 54 ± 1°C in F3. Post-hoc analysis showed that F0 and F1 did not differ significantly, while F2 did not differ significantly from either F0, F1, or F3. F3 showed a significant difference from F0 and F1 ($p < 0.05$). Thus, although a gradual numerical increase in melting point was observed, significant differences were only found between selected formulations. The melting point is an important quality parameter of lip balm because it reflects the thermal behavior and physical stability of the formulation during storage and application (Endriyatno et al., 2024). The observed variation in melting point may be associated with changes in the formulation matrix resulting from the incorporation of increasing concentrations of *Aloe vera* gel and the corresponding adjustment of white petrolatum, while the amount of cera alba remained constant. Cera alba has a relatively high melting point (61–65°C) and contributes to the structure and consistency of semisolid preparations (Suena et al., 2022), whereas white petrolatum has a lower melting range (approximately 38–60°C) and contributes to the softness of the preparation(Zuhriah et al., 2021). Therefore, changes in the relative proportions of these components may have contributed to the observed variation in melting point. However, this represents a possible mechanism rather than a confirmed causal relationship, as the individual contribution of each component was not independently evaluated in this study. Overall, increasing *Aloe vera* gel concentration was associated with a gradual numerical increase in melting point, with statistically significant differences observed only between selected formulation groups based on the pairwise post-hoc analysis.

The spreadability test results showed that the spreadability of the lip balm formulations increased with increasing concentrations of *Aloe vera* gel. Formulations containing higher concentrations of *Aloe vera* gel exhibited greater spreadability values (Firdausi Imani et al., 2022). This increase may be associated with the incorporation of aqueous *Aloe vera* gel into the formulation matrix, which may influence the consistency and ease of spreading of the lip balm. The high water content of *Aloe vera* gel (approximately 98-99.5%) may contribute to this effect (Nalimu et al., 2021). However, this proposed mechanism should be interpreted cautiously, as other changes in the formulation matrix may also influence spreadability. Statistical analysis demonstrated a significant difference in spreadability among the formulations. Nevertheless, the incorporation of 30–40% aqueous *Aloe vera* gel may also affect emulsion or phase stability, syneresis, water activity, and microbial susceptibility. These parameters were not evaluated in the present study and should therefore be considered limitations. Further stability and microbiological assessments are needed to confirm the effect of the high aqueous gel content on the overall quality of the lip balm formulations.

The photoprotective potential of the formulations was evaluated in vitro by determining the estimated SPF values using the Mansur spectrophotometric method. The absorbance of the lip balm solutions was measured using a UV–Vis spectrophotometer and used to calculate the estimated SPF values (Endriyatno et al., 2024). F0, the formulation without *Aloe vera* gel, showed an estimated SPF value of 3.078, corresponding to minimal protection (SPF 2–<12). This value represents the overall UV-absorbing response of the complete formulation matrix and cannot be attributed to a specific ingredient. The incorporation of *Aloe vera* gel increased

the estimated SPF values, with F1, F2, and F3 showing values of 19.238, 20.672, and 22.399, respectively. These values correspond to moderate protection (SPF 12–<30). A similar increase in SPF following *Aloe vera* incorporation was reported by (Hendrawati et al., 2020). However, the observed increase should be interpreted as an association rather than evidence of a specific photoprotective mechanism, as the contribution of individual *Aloe vera* constituents was not independently evaluated. The reported SPF values are estimated in vitro values obtained using the Mansur method and should be regarded as preliminary screening results rather than regulatory or labeled SPF claims. Appropriate validated and in vivo SPF testing would be required to support regulatory SPF claims.

The increase in estimated SPF values with increasing *Aloe vera* gel concentration may be related to bioactive compounds reported to have UV-absorbing and antioxidant properties, such as aloin and flavonoids (Ray et al., 2013; Fujishiro et al., 2024). However, this remains a literature-based hypothesis because these compounds were not quantitatively analyzed in the present study. In addition, the use of n-hexane may not efficiently extract relatively polar compounds. Therefore, further phytochemical profiling and standardization are needed to identify the compounds contributing to the observed SPF values. Statistical analysis showed that *Aloe vera* gel concentration significantly affected the estimated SPF values of the formulations.

Conclusion

The lip balm formulations containing 30%, 35%, and 40% *Aloe vera* gel showed acceptable physical characteristics based on the parameters evaluated in this study. F0, which served as the base control without *Aloe vera* gel, showed an estimated in vitro SPF value of 3.078 (minimal protection), while F1, F2, and F3 showed estimated in vitro SPF values of 19.238, 20.672, and 22.399, respectively, corresponding to moderate protection. Statistical analysis indicated that *Aloe vera* gel concentration significantly affected the estimated SPF values. However, the observed increase should be interpreted as an association rather than a confirmed dose-dependent effect. Further validated and in vivo SPF testing is required to support any regulatory SPF claim.

SUGGESTIONS

Aloe vera gel shows potential as a natural ingredient for lip balm formulations with photoprotective potential. Further studies are recommended to evaluate formulation stability, microbiological quality, phytochemical standardization, photostability, and SPF using validated methods. In vivo and clinical studies are also needed to confirm the photoprotective efficacy and safety of the formulation before practical application.

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DECLARATION OF INTEREST

The authors declare that there is no conflict of interest

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