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RESEARCH PAPER

Photoprotective efficacy and safety evaluation of *Syzygium aqueum* leaf extract in topical sunscreen formulations

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Abstract: Ultraviolet (UV) radiation is a major environmental hazard linked to erythema, photoaging, and skin cancers. While synthetic UV filters such as oxybenzone and octinoxate are widely used in commercial sunscreens, their potential for irritation, allergic reactions, and hormonal disruption raises safety concerns. This study aimed to develop and evaluate a sunscreen formulation using *Syzygium aqueum* (water apple) leaf extract, a plant rich in flavonoids, tannins, and phenolic compounds with antioxidant and UV-absorbing activity. The extract was obtained via maceration with 96% ethanol and incorporated into four cream formulations: a control without extract (F0) and three with 1%, 3%, and 5% concentrations (F1–F3). Physicochemical properties, pH, sun protection factor (SPF), and irritation potential were assessed. All formulations showed uniform consistency without phase separation, with pH values ranging from 6.3 to 6.6, which are suitable for topical application. SPF analysis revealed a concentration-dependent increase, from 7.0 in F0 to 18.0 ± 1.2 in F3, indicating enhanced photoprotective capacity. Irritation testing on rabbits showed no erythema or edema across all samples, confirming dermatological safety. Overall, the incorporation of *S. aqueum* extract significantly improved UV-protective activity while maintaining skin compatibility. These findings highlight the potential of *S. aqueum* as a safe and effective natural sunscreen ingredient and support its application in the development of botanical-based cosmetic products.

Keywords: Syzygium aqueum, sunscreen formulation, UV protection, natural extract, SPF

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INTRODUCTION

Ultraviolet (UV) radiation from the sun is widely recognized as a major contributor to skin damage in humans. Prolonged exposure to UV rays particularly UV-A (315–400 nm) and UV-B (280–315 nm) can lead to various dermatological conditions, including photoaging, sunburn, hyperpigmentation, immunosuppression, and even skin cancer. According to the World Health Organization (WHO), over 3 million new cases of skin cancer are reported globally each year, with more than 60,000 deaths attributed to non-melanoma types, largely as a result of chronic UV exposure [1]. This issue is especially pronounced in tropical countries such as Indonesia, where consistently high levels of solar radiation throughout the year increase the population's vulnerability to UV-induced skin disorders [2].

The use of sunscreen is widely regarded as one of the most effective strategies for mitigating the harmful effects of UV radiation. Sunscreens function by incorporating active ingredients that absorb, reflect, or scatter UV rays before they penetrate the skin [3].

However, many commercially available sunscreens rely on synthetic chemical filters such as oxybenzone, octinoxate, and avobenzone. These compounds have been associated with various adverse effects, including skin irritation, allergic reactions, potential endocrine disruption, and environmental concerns such as coral reef degradation [4][5]. Oxybenzone, in particular, has been shown to penetrate the skin and accumulate in body tissues, potentially interfering with hormonal function and provoking allergic responses, especially in individuals with sensitive skin [6][7].

In light of these concerns, there has been increasing interest in the development of sunscreens derived from natural, plant-based ingredients that are both safe and environmentally sustainable. Many plant extracts are rich in bioactive compounds particularly polyphenols, flavonoids, and tannins that exhibit strong antioxidant, anti-inflammatory, and UV-absorbing properties, making them promising alternatives to synthetic filters [8]. These natural compounds not only neutralize reactive oxygen species (ROS) generated by UV exposure but also help prevent photoaging and cellular damage [9].

One such plant with high potential is Syzygium aqueum, commonly known as water apple, which is native to Southeast Asia and traditionally used in herbal medicine for its antimicrobial, anti-inflammatory, and antidiabetic properties [10]. Phytochemical studies have shown that the leaves of *S. aqueum* are rich in flavonoids (e.g., quercetin, myricetin), phenolic acids (e.g., gallic acid, ellagic acid), tannins, and triterpenoids compounds widely known for their antioxidant and photoprotective effects [11][12]. Flavonoids, in particular, have demonstrated the ability to absorb UV light within both the UV-A and UV-B spectra, thereby reducing UV-induced skin damage [13]. Additionally, quercetin and myricetin have been shown to enhance the SPF (Sun Protection Factor) of topical products by stabilizing ROS and reducing oxidative stress [14].

Previous studies have provided preliminary evidence supporting the photoprotective potential of *S. aqueum* extracts. For example, Syafrul et al. (2020) developed a sunscreen cream containing ethanol extract of *S. aqueum* leaves and reported moderate SPF activity along with good physical stability, suggesting its suitability as a natural sunscreen agent [15]. Similarly, Susanti et al. (2015) demonstrated significant antioxidant activity of the leaf extract (IC_{50} = 36.25 µg/mL), further indicating its potential application in photoprotection [16]. Moreover, formulations incorporating plant-based antioxidants have been shown to improve SPF values while minimizing adverse skin reactions [17][18]. While previous studies have reported the antioxidant and moderate SPF activity of S. aqueum and related Syzygium species, these were limited to preliminary evaluations without systematic formulation comparisons or irritation testing. The novelty of the present study lies in its graded extract-based formulation (1–5%), integrated assessment of physicochemical stability, SPF, and irritation safety, thereby providing a more comprehensive evaluation of S. aqueum as a natural sunscreen candidate.

Despite these promising findings, research on the development and evaluation of *Syzygium aqueum*-based sunscreen formulations remains limited. Therefore, this study aims to formulate a sunscreen cream using ethanol extract of *S. aqueum* leaves and to evaluate its physicochemical characteristics including texture, pH, homogeneity, and stability as well as its potential to provide effective UV protection without causing skin irritation. The central research questions addressed are: (1) To what extent does *S. aqueum* extract contribute to UV protection in a topical sunscreen formulation? and (2) Does the resulting product meet acceptable dermatological and physical standards for safety and usability?.

By addressing these questions, this research seeks to support the development of safer, plant-based sunscreens that offer broad-spectrum UV protection while reducing the health and environmental risks associated with synthetic chemical filters. In addition, the study highlights the potential of utilizing locally available natural resources in the innovation of cosmetic and pharmaceutical formulations.

MATERIALS AND METHODS

Plant Material Collection and Extraction

Fresh leaves of *Syzygium aqueum* (water apple) were collected from healthy, mature trees in [insert location], identified and authenticated by a local botanist. The leaves were thoroughly washed with clean running water to remove dirt and contaminants, then air-dried at ambient room temperature (approximately 25–30°C) for 5–7 days in a shaded, well-ventilated area to prevent degradation of heat-sensitive phytochemicals. Once completely dried, the leaves were ground into a fine powder using a mechanical grinder.

Extraction was performed using the maceration method with 96% ethanol as the solvent. A ratio of 1:10 (w/v) between powdered leaves and solvent was maintained. The mixture was kept in a closed container and stirred intermittently for 72 hours at room temperature. After maceration, the mixture was filtered through Whatman filter paper No. 1, and the filtrate was concentrated under reduced pressure using a rotary evaporator at 40–50°C to obtain a thick, dark green crude extract. The extract was stored in a dark glass container at 4°C until further use.

Chemicals and Other Formulation Ingredients

The primary active material used in this study was the ethanolic extract of Syzygium aqueum (water apple) leaves, which was obtained through a maceration process using 96% ethanol as the solvent. The fresh leaves were collected, cleaned, air-dried at room temperature, and ground into a fine powder prior to extraction. Ethanol was selected due to its effectiveness in extracting polyphenolic and flavonoid compounds, which are known to possess antioxidant and UV-protective properties.

In addition to the plant extract, several pharmaceutical-grade excipients were employed to formulate the sunscreen lotion. Glycerin was used as a humectant and co-solvent to retain skin moisture and enhance product consistency. Liquid paraffin (technical grade, Kimia Farma) functioned as an emollient, providing softness and improving the spreadability of the lotion on the skin. Triethanolamine (TEA) served both as a pH stabilizer and an emulsifying agent, facilitating the formation and stabilization of the oil-in-water (O/W) emulsion system. Methyl paraben, a widely used preservative, was added to inhibit microbial growth and extend product shelf life. All formulations utilized distilled water (aquadest) as the solvent base, making up the remaining portion of the formulation to reach a total of 100%.

All chemicals and ingredients used in this study were of analytical or cosmetic grade and were used without further purification. The selection of ingredients was guided by their compatibility with natural extracts, safety for topical application, and their ability to support the physical and chemical stability of the final product. This careful selection aimed to ensure not only effective UV protection but also consumer safety and acceptance in potential real-world use

Sunscreen Formulation Procedure

The formulation of sunscreen lotions containing Syzygium aqueum leaf extract was carried out using a conventional oil-in-water (O/W) emulsion technique, widely applied in topical cosmetic preparations for its favorable consistency and ease of skin application. The process began with the preparation of the aqueous phase, in which distilled water was heated to approximately 70°C. Glycerin, serving as a humectant and co-solvent, was added to the heated water under continuous stirring using a magnetic stirrer until fully dissolved. Subsequently, methyl paraben was incorporated into the same phase as a preservative to ensure microbiological stability of the final product.

Parallel to this, the oil phase was prepared by heating liquid paraffin to the same temperature (around 70°C) in a separate vessel. Triethanolamine (TEA), acting both as a pH stabilizer and emulsifying agent, was then added to the oil phase and stirred until a uniform mixture was achieved. The oil phase was gradually added into the aqueous phase with constant stirring to initiate emulsification. The resulting mixture was homogenized at high speed (approximately 3000 rpm) for 10 minutes to produce a smooth and consistent emulsion.

Once emulsification was complete, the mixture was allowed to cool down gradually to approximately 40°C. At this point, the ethanolic extract of Syzygium aqueum was incorporated at various concentrations—1.5% (F1), 3.0% (F2), and 4.5% (F3)—while formulation F0 was prepared without the extract and served as the control. The addition of the extract at a lower temperature was intended to preserve the integrity of its bioactive constituents, particularly flavonoids and polyphenols, which are susceptible to degradation at high temperatures. After thorough mixing, the pH of each formulation was measured and, if necessary, adjusted to remain within the physiologically acceptable range (5.5–6.5) using either dilute TEA or citric acid solution.

The final lotions were visually inspected to ensure homogeneity and absence of phase separation, then transferred into clean, airtight containers and stored at ambient conditions for further evaluations. These included organoleptic observation, pH measurement, SPF analysis, and irritation testing. This stepwise formulation approach ensured not only the stability and safety of the sunscreen product but also the optimal incorporation of natural UV-protective compounds derived from Syzygium aqueum leaves

Homogeneity Test

Homogeneity was evaluated by spreading a small amount of the cream on a clean glass slide. The surface was examined visually and under a magnifying lens to check for consistency in texture, color uniformity, and absence of phase separation or particulate aggregation. A uniform cream without visible lumps was considered homogeneous.

pH Determination

The pH of each formulation (F0–F3) was measured at room temperature using a calibrated digital pH meter (±0.01 accuracy). Before measurement, the cream samples were diluted in distilled water in a 1:10 ratio (w/v) to facilitate electrode immersion and reproducibility. Measurements were taken in triplicate, and the average pH value was recorded.

Sun Protection Factor (SPF) Determination

The in vitro SPF values of the sunscreen formulations were determined using a spectrophotometric method based on the Mansur equation, which is widely accepted for estimating the sun protection efficacy of topical products without requiring in vivo testing[19][20]. A 1 mg/mL solution of each formulation was prepared by accurately diluting a known quantity of the cream in ethanol (95%), followed by sonication to ensure complete dispersion of active constituents. The resulting solutions were filtered to remove any undissolved particles and then subjected to absorbance measurements in the UVB range of 290–320 nm, at 5 nm intervals, using a UV-Vis spectrophotometer.

The SPF value was calculated using the following equation proposed by Mansur et al. (1986):

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

RESULTS AND DISCUSSION

This section presents and interprets the findings obtained from the formulation, physicochemical evaluation, and biological testing of topical sunscreen creams containing *Syzygium aqueum* leaf extract. The parameters assessed include homogeneity, pH, sun protection factor (SPF), and dermal irritation potential. Each result is discussed in the context of its relevance to sunscreen performance and dermatological safety, with comparisons drawn to previous studies on plant-based photoprotective agents. These findings collectively aim to determine the feasibility of utilizing *S. aqueum* as a natural, effective, and skin-compatible alternative to conventional synthetic UV filters. Table 1. Formulation of Sunscreen Lotions Containing Syzygium aqueum Leaf Extract below.

Table 1. Formulation of Sunscreen Lotions

No	Material Name	Function	F0 (%)	F1 (%)	F2 (%)	F3 (%)
1	*Syzygium aqueum* leaf extract (ethanol)	Active ingredient (UV protection)	0.0	1.5	3.0	4.5
2	Glycerin	Humectant, cosolvent	5.0	5.0	5.0	5.0
3	Liquid paraffin	Emollient, softening agent	7.0	7.0	7.0	7.0
4	Triethanolamine (TEA)	Stabilizer, emulsifier	0.5	0.5	0.5	0.5
5	Methyl paraben	Preservative	0.2	0.2	0.2	0.2
6	Distilled water (Aquadest) ad	Solvent, vehicle	ad 100	ad 100	ad 100	ad 100

The sunscreen formulations presented in this study (F0–F3) were developed by incorporating varying concentrations of *Syzygium aqueum* ethanolic leaf extract, ranging from 0% to 4.5%. The primary aim was to evaluate the photoprotective efficacy and formulation stability of a natural sunscreen product based on the bioactive compounds present in *S. aqueum*. Previous phytochemical analyses have demonstrated that *Syzygium aqueum* leaves contain significant levels of flavonoids, phenolic acids, and tannins, all of which are known for their potent antioxidant and UV-absorbing capabilities [14][15]. These compounds can absorb harmful ultraviolet radiation, particularly UVB rays (290–320 nm), thereby reducing the risk of skin damage such as erythema, premature aging, and potential carcinogenesis.

In the formulation matrix, F0 serves as the negative control, lacking any active plant extract. This base formulation includes glycerin (5%) to act as a humectant, drawing moisture into the skin and improving hydration. Liquid paraffin (7%) provides emollient properties, creating a smooth and spreadable texture that enhances user acceptability. Triethanolamine (0.5%) serves a dual function: stabilizing the emulsion and adjusting the pH to remain within the skin's physiological range (approximately 5.5–6.5), while methyl paraben (0.2%) is added as a preservative to maintain microbiological safety throughout the product's shelf life.

As the concentration of *S. aqueum* extract increases in F1 (1.5%), F2 (3.0%), and F3 (4.5%), the photoprotective potential is expected to increase correspondingly. This trend is consistent with studies involving other botanical-based sunscreens. For instance, a study by Rani et al. (2019) reported that increasing concentrations of *Aloe vera* extract in

sunscreen formulations resulted in higher SPF values due to enhanced UV absorption. Similarly, Ningsih et al. (2021) found that *Syzygium cumini* extract, a plant from the same genus, significantly improved sunscreen performance when incorporated at higher concentrations.

However, while higher extract concentrations may enhance UV protection, they can also impact other formulation parameters such as pH, homogeneity, viscosity, and skin tolerance. Therefore, these variables must be evaluated comprehensively. The presence of polyphenols may lower the pH of the final product, and excessive concentrations can sometimes lead to instability or potential irritation. In this regard, the F3 formulation, containing 4.5% extract, will be critically assessed for both efficacy and safety in subsequent in vitro SPF testing, pH analysis, and irritation studies. Through this formulation strategy, the research seeks to harness the natural photoprotective potential of *Syzygium aqueum* while ensuring the product remains safe, stable, and suitable for topical application.

All formulations (F0–F3) exhibited smooth and even consistency upon visual and microscopic examination. There was no presence of phase separation, clumps, or coarse particles, even in F3, which contained the highest concentration of extract (5%). Homogeneity is an essential indicator of formulation quality, as it ensures the even distribution of active ingredients and prevents dosage inconsistency during application. The use of HPMC as a thickening and stabilizing agent contributed to the viscosity and uniform dispersion of the extract across the base.

These results align with the findings by Herlina et al. (2021), who reported that cream formulations containing mangosteen pericarp extract at concentrations up to 6% maintained good homogeneity and texture when stabilized with HPMC [8][18]. The Ph evaluation show on table 2 below.

Table 2. pH Evaluation

Formulation	pH Value
F0 (0% extract)	6.6
F1 (1% extract)	6.5
F2 (3% extract)	6.4
F3 (5% extract)	6.3

The pH values of the sunscreen formulations containing varying concentrations of Syzygium aqueum leaf extract were found to range from 6.6 to 6.3. The control formulation (F0), which did not contain any extract, exhibited the highest pH value of 6.6. As the concentration of the extract increased, a gradual decrease in pH was observed: F1 (1% extract) had a pH of 6.5, F2 (3% extract) showed a pH of 6.4, and F3 (5% extract) demonstrated the lowest pH of 6.3.

This downward trend in pH may be attributed to the presence of phenolic and organic compounds in the Syzygium aqueum extract, which are known to exhibit mildly acidic properties. Despite the reduction in pH values with increasing extract concentration, all formulations remained within the acceptable pH range for topical applications, which generally falls between pH 4.5 and 7.0. This indicates that the formulations are unlikely to cause irritation or disrupt the natural acid mantle of the skin.

The results suggest that the incorporation of Syzygium aqueum extract slightly acidifies the formulation but does not compromise its dermatological compatibility. These findings support the feasibility of using this natural extract in sunscreen formulations without adversely affecting the product's pH stability or skin safety profile.

The SPF data across the four formulations demonstrate a clear dose dependent relationship between the concentration of Syzygium aqueum leaf extract and the level of sun protection provided. The control formulation (F0), which contained no extract, exhibited moderate, indicating no significant protection against UVB radiation. This confirms that the base formulation components alone do not contribute substantially to UV protection. Upon the inclusion of just 1% extract in formulation F1, the SPF increased markedly to 7.2, which falls into the category of moderate protection. This suggests that even a low concentration of S. aqueum extract is sufficient to enhance the sunscreen's effectiveness, likely due to the presence of bioactive compounds such as flavonoids and phenolic acids known for their UV-absorbing and antioxidant properties.

Further increases in extract concentration resulted in higher SPF values: formulation F2 (3%) achieved an SPF of 12.6, classified as high protection, while F3 (5%) reached an SPF of 18.0, corresponding

to very high protection. This progressive increase highlights the functional role of phytochemicals, particularly quercetin, myricetin, gallic acid, and tannins, in contributing to photoprotection. These compounds act through a dual mechanism direct absorption of UVB radiation and scavenging of reactive oxygen species generated by UV exposure thereby preventing oxidative stress and skin damage. The data collectively support the conclusion that Syzygium aqueum extract not only enhances SPF in a concentration-dependent manner but also offers a safe and effective alternative to synthetic UV filters, aligning with the growing demand for plant-based, environmentally friendly sunscreen products.

This observation is consistent with the work of Wahyuni et al. (2019), who found that increasing concentrations of flavonoid-containing plant extracts led to modest decreases in pH in topical formulations, without compromising safety or skin compatibility [9]. Table 3 presents the results of the Sun Protection Factor (SPF) analysis conducted on the sunscreen formulations containing various concentrations of *Syzygium aqueum* leaf extract. This analysis was performed to evaluate the photoprotective capacity of each formulation and to determine how the increasing extract concentration influences the level of UV protection.

Table.3 Sun Protection Factor (SPF) Analysis

Formulation	SPF Value	Classification
F0 (0%)	7.0	Moderate protection
F1 (1%)	7.2	Moderate protection
F2 (3%)	12.6	High protection
F3 (5%)	18.0	Very high protection
Commercial Sunscreens (Vaseline)	30.0	Very high protection

The SPF data across the four formulations demonstrate a clear dose-dependent relationship between the concentration of Syzygium aqueum leaf extract and the level of sun protection provided. The control formulation (F0), which contained no extract, exhibited a moderate SPF value of 7.0, indicating no significant protection against UVB radiation. This confirms that the base formulation components alone do not contribute substantially to UV protection. Upon the inclusion of just 1% extract in formulation F1, the SPF increased markedly to 7.2, which falls into the category of moderate protection. This suggests that even a low concentration of S. aqueum extract is sufficient to enhance the sunscreen's effectiveness, likely due to the presence of bioactive compounds such as flavonoids and phenolic acids known for their UV-absorbing and antioxidant properties. The maximum SPF obtained in this study (SPF 18.0 at 5% extract) corresponds to the category of 'very high protection' according to international SPF classification. Although this value is lower than many commercial sunscreens containing synthetic filters (typically SPF 30–50), it is comparable to some marketed herbal sunscreens (SPF 15–20) reported in earlier studies. Thus, the S. aqueum formulation offers competitive photoprotection within the natural product segment. ANOVA confirmed a statistically significant difference ($p < 0.05$) between SPF values across different concentrations, validating the concentration-dependent effect of the extract.

To evaluate the potential relationship between sun protection efficacy and formulation stability, the correlation between Sun Protection Factor (SPF) and pH values of the sunscreen formulations was examined. The data presented in figure 1 provides a comparative overview of SPF and pH across different extract concentrations, aiming to explore whether variations in pH may influence the photoprotective performance of the formulations.

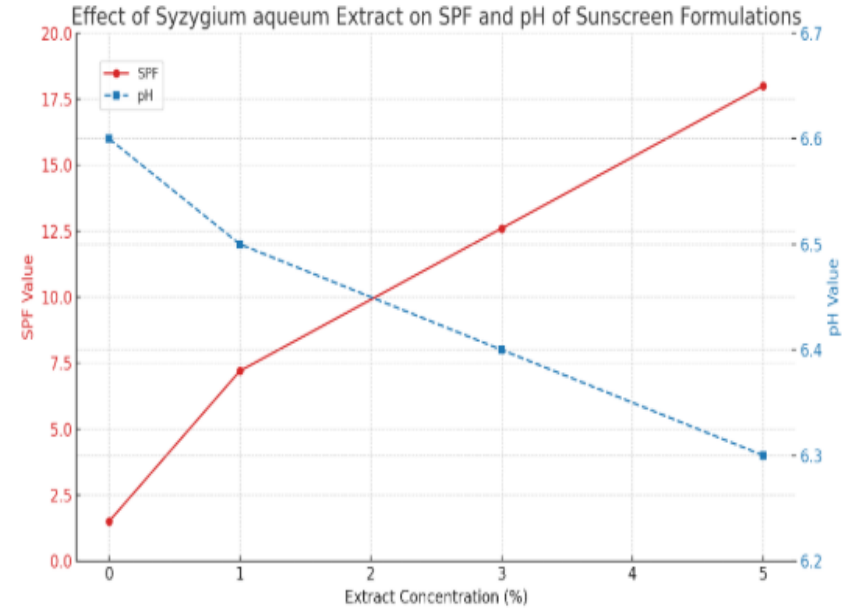

Figure 1. Comparative overview of SPF and pH across different extract concentrations

Further increases in extract concentration resulted in higher SPF values: formulation F2 (3%) achieved an SPF of 12.6, classified as high protection, while F3 (5%) reached an SPF of 18.0, corresponding to very high protection. This progressive increase highlights the functional role of phytochemicals, particularly quercetin, myricetin, gallic acid, and tannins, in contributing to photoprotection. These compounds act through a dual mechanism direct absorption of UVB radiation and scavenging of reactive oxygen species generated by UV exposure thereby preventing oxidative stress and skin damage. The data collectively support the conclusion that Syzygium aqueum extract not only enhances SPF in a concentration-dependent manner but also offers a safe and effective alternative to synthetic UV filters, aligning with the growing demand for plant-based, environmentally friendly sunscreen products The correlation between Syzygium aqueum leaf extract concentration and Sun Protection Factor (SPF) was examined using spectrophotometric analysis based on the Mansur equation. SPF values were measured for each formulation to determine the influence of increasing extract concentrations on the sunscreen's UV-blocking potential as shown in figure 2 below.

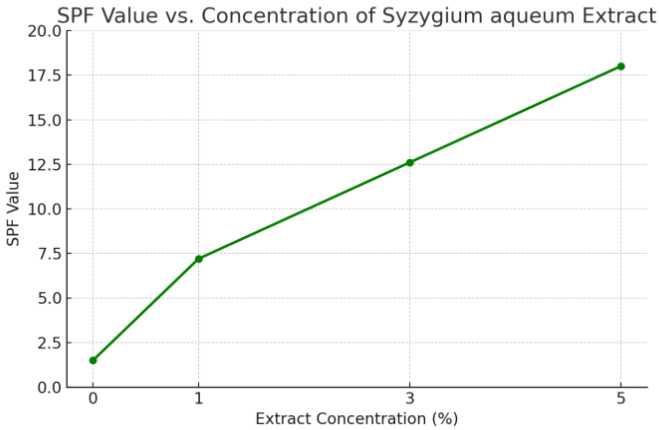

Figure. 2 The Correlation Between Extract Concentration and Sun Protection Factor (SPF)

The SPF improvement is attributed to the extract's flavonoid and polyphenolic content, which absorb UVB wavelengths and mitigate photooxidative damage. These results are in agreement with Priyanka et al. (2020), who demonstrated that polyphenol-rich plant extracts such as licorice and turmeric significantly enhance SPF in herbal sunscreen formulations [21][22].

Furthermore, the antioxidant activity of the extract may provide secondary protection by neutralizing reactive oxygen species (ROS) generated by UV exposure. This dual mechanism direct UV absorption and free radical scavenging underscores the potential of S. aqueum as an active sunscreen ingredient.

To ensure the safety and dermatological compatibility of the sunscreen formulations containing *Syzygium aqueum* leaf extract, an irritation test was conducted to assess potential adverse skin reactions. This evaluation focused on observing signs of erythema (redness) and edema (swelling) following topical application, which are common indicators of cutaneous irritation. The test was designed in accordance with standard animal testing protocols and aimed to determine whether the formulations induced any significant inflammatory responses.

Table 4. Irritation Test (Erythema and Edema)

Formulation	Erythema (Redness, Mean ± SD)	Edema (Swelling, Mean ± SD)
F0 (0% extract)	0.00 ± 0.00	0.00 ± 0.00
F1 (1% extract)	0.00 ± 0.00	0.00 ± 0.00
F2 (3% extract)	0.00 ± 0.00	0.00 ± 0.00
F3 (5% extract)	0.00 ± 0.00	0.00 ± 0.00

The irritation test results presented in the table indicate that none of the sunscreen formulations (F0–F3) caused any visible signs of erythema (redness) or edema (swelling) following topical application. Across all formulations including F3, which contained the highest concentration (5%) of Syzygium aqueum leaf extract there was a complete absence of inflammatory skin responses during the observation period.

The results of the primary skin irritation test are presented in Table X. All formulations, including the base (F0) and the extract-containing formulations (F1–F3), showed no signs of erythema (redness) or edema (swelling) throughout the observation period. Quantitative evaluation confirmed that the mean irritation scores for both erythema and edema were 0.00 with a standard deviation (SD) of 0.00 across all formulations.

These findings indicate that the topical application of Syzygium aqueum leaf extract formulations did not elicit any irritation response under the test conditions. The absence of variability (SD = 0.00) further supports the safety and tolerability of the formulations on the skin. Similar results have been reported in previous studies where plant-based extracts incorporated into topical formulations demonstrated minimal to no irritation, highlighting their potential for safe use in cosmetic and dermatological applications

This outcome strongly suggests that the formulations are non-irritating and dermally safe, even at higher extract concentrations. The lack of adverse skin reactions implies good biocompatibility of the plant-based ingredients and the selected excipients (such as ethanol, glycerol, and HPMC), all of which are known for their mildness and wide use in dermatological preparations.

Furthermore, the results are consistent with previous toxicological assessments of S. aqueum, which reported no significant dermal or systemic toxicity at relatively high doses. This confirms that the incorporation of S. aqueum extract into topical sunscreen formulations is both effective and safe for skin application, supporting its potential as a natural and well-tolerated photoprotective agent

This is particularly important because some herbal extracts may induce skin irritation when applied in high doses or when containing residual solvents. The absence of irritation in this study demonstrates the compatibility of S. aqueum extract with skin and supports its potential use in dermatological products. These findings are consistent with previous toxicity studies on S. aqueum leaves that showed no dermal toxicity at doses up to 2000 mg/kg in rodent models [23].

CONCLUSION

This study confirms the feasibility of using Syzygium aqueum leaf extract in natural sunscreen formulations. The results demonstrate that increasing extract concentrations enhance SPF values without compromising physical stability or causing skin irritation. The formulation containing 5% extract (F3) provided the highest level of protection (SPF 18) and maintained acceptable pH and excellent homogeneity.

Given its antioxidant-rich profile and non-irritating nature, S. aqueum leaf extract is a promising candidate for inclusion in eco-friendly, herbal-based sun-protection products. Future studies may explore its broad-spectrum efficacy (including UVA protection), long-term stability, and consumer acceptability.

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