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SUN PROTECTION FACTOR (SPF) AND IRRITATION EVALUATION OF SUNSCREEN LOTION CONTAINING ETHANOLIC EXTRACT OF FIG FRUIT (*Ficus racemosa* L.)

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ABSTRACT

Excessive and prolonged exposure to sunlight may cause pigmentation, wrinkles, erythema, and an increased risk of skin cancer. Therefore, sunscreen products are needed to protect the skin from ultraviolet radiation. Fig fruit (*Ficus racemosa* L.) contains bioactive compounds such as flavonoids, steroids, saponins, and tannins that potentially act as natural sunscreen agents. This study aimed to evaluate the Sun Protection Factor (SPF) and irritation potential of sunscreen lotion containing ethanolic extract of *Ficus racemosa* L. fruit. The extract was obtained by maceration using 96% ethanol. SPF values were determined by UV-Vis spectrophotometry, and irritation testing was conducted using the Human 4-Hour Patch Test with 15 healthy female volunteers. The SPF values of the formulation containing 0 g (F_0), 0.125 g (F_1), 0.250 g (F_2), 0.500 g (F_3), and 1.000 g (F_4) extract were 1.3473, 1.5970, 2.4371, 4.1191, and 4.3891, respectively. Based on SNI number 16-4399-1996, only F_3 and F_4 fulfilled the minimum SPF requirement of 4. No erythema or edema was observed in all formulations. These results indicate that higher extract concentration increased sunscreen activity, and F_3 and F_4 showed the highest SPF values with moderate sunscreen protection.

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INTRODUCTION

Indonesia is located in a tropical region with high levels of solar radiation year-round. Continuous exposure to ultraviolet (UV) radiation can lead to various skin problems, including erythema, hyperpigmentation, premature aging, and increased risk of skin cancer (Rodríguez-Martínez et al., 2025; Watson et al., 2016). Therefore, the use of sunscreen products is essential for protecting the skin from harmful UV radiation (Sharma et al., 2020). Most commercial sunscreen formulations contain synthetic UV filters such as oxybenzone, octyl methoxycinnamate, zinc oxide, and titanium dioxide (Dario et al., 2025). Although these compounds are effective, prolonged use has been associated with adverse effects such as skin irritation, hypersensitivity reactions, and potential environmental concerns. In addition, some inorganic UV filters are formulated as nanoparticles, which may increase production costs and limit access to the development of alternative sunscreen agents derived from natural sources (Sitinjak et al., 2025).

Natural products rich in flavonoids and phenolic compounds have attracted considerable attention due to their ability to absorb UV radiation and neutralize free radicals through their conjugated aromatic structures (He et al., 2021). Plant extracts are considered promising natural photoprotective agents due to the presence of various bioactive constituents, including flavonoids, polyphenols, tannins, and vitamin C, which may help protect the skin from UV-induced damage (Iskandar et al., 2025; Rahmayanti et al., 2025). One promising plant is fig fruit (*Ficus racemosa* L.), which is widely distributed in tropical regions. Previous studies have shown that this plant contains various bioactive compounds such as flavonoids, tannins, saponins, steroids, and other phenolic compounds, along with strong antioxidant activity (Pant et al., 2025; Suil et al., 2025). These phytochemicals are known to contribute to photoprotective effects and may enhance the ability of the skin to resist UV-induced damage (Roquete Amparo et al., 2022). Recent research has also demonstrated the sunscreen potential of *Ficus racemosa* fruit extract. A cream formulation containing ethanolic extract obtained by Microwave-Assisted Extraction (MAE) exhibited photoprotective activity, with the highest SPF value of 8.82 observed at a 10% extract concentration (Andry et al., 2026). These findings support the potential application of *Ficus racemosa* fruit as a natural sunscreen ingredient.

In our previous study, a lotion formulation containing ethanolic extract of *Ficus racemosa* L. fruit was successfully developed and evaluated for physicochemical properties, including pH, homogeneity, spreadability, and three-cycle stability (Suryani et al., 2024). The formulations demonstrated acceptable characteristics for topical application. However, information regarding the functional performance of these formulations, particularly in terms of Sun Protection Factor (SPF) value and skin irritation safety, remains limited. Therefore, this study aimed to evaluate the SPF values and irritation potential of sunscreen lotion containing ethanolic extract of *Ficus racemosa* L. fruit. This study is expected to provide additional scientific evidence regarding the efficacy and safety of *Ficus racemosa* L. fruit extract as a potential natural sunscreen active ingredient.

METHOD

MATERIALS AND INSTRUMENTS

The materials used in this study consisted of fresh fruit of *Ficus racemosa* L., which was collected from Dusun Sembah, Sepit Village, Keruak District, East Lombok, West Nusa Tenggara, Indonesia. Other materials included ethanol 96% (Merck), stearic acid (Sigma-Aldrich), liquid paraffin (Chemica Karya), methyl paraben, glycerin, propyl paraben, triethanolamine (TEA) (Sigma-Aldrich), filter paper, and distilled water.

The instruments used were an analytical balance (KERN), oven (Memmert), UV-Vis spectrophotometer (Shimadzu UV-1900i), hotplate (Thermo Scientific), rotary evaporator (B-ONE), water bath (Memmert), blender (Phillips), Buchner funnel with vacuum filtration system, vacuum desiccator, glassware set, spatula, and magnetic stirrer.

SAMPLE PREPARATION

A total of 1 kg of fig fruit was washed thoroughly with running water, drained, and sliced into pieces. The samples were dried in an oven at 60 °C for 12 h, then ground using a blender and sieved through a 200-mesh sieve to obtain fine powder. Drying and size reduction were performed to minimize moisture content and increase extraction efficiency (Harborne, 1998).

EXTRACTION OF *Ficus racemosa* L.

A 120 g fine powder was macerated with 600 mL of 96% ethanol (ratio 1:5 b/v) for 24 h at room temperature with occasional stirring. The residue was re-macerated using fresh solvent for three consecutive cycles. All filtrates were combined and concentrated using a rotary evaporator at 50 °C under reduced pressure, followed by further evaporation on a water bath at 60 °C until a viscous extract was obtained. The extraction yield was calculated as a percentage yield based on dry sample weight using Equation (1) (Isac-Garcia et al., 2015).

$$\text{Yield (\%)} = \frac{\textit{Weight of extract obtained}}{\textit{weight of dry powder}} \times 100 \ldots\text{(eq.1)}$$

LOTION FORMULATION

Five lotion formulations were prepared, consisting of F_0 (control, without extract), F_1 (0.125 g), F_2 (0.250 g), F_3 (0.500 g), and F_4 (1.000 g) of *Ficus racemosa* fruit extract. The complete composition of each formulation is presented in Table 1, and modifying followed by the previous study (Lumantow et al., 2023).

Table 1. Formulation of lotion containing ethanol extract of *Ficus racemosa* L.

Ingredient	Formula				
	F_0	F_1	F_2	F_3	F_4
Extract (g)	0	0.125	0.250	0.500	1.000
Stearic acid (g)	5	5	5	5	5
Liquid paraffin (mL)	4	4	4	4	4
Propyl paraben (g)	0.08	0.08	0.08	0.08	0.08
Methyl paraben (g)	0.1	0.1	0.1	0.1	0.1
Glycerin (mL)	4	4	4	4	4
TEA (g)	1.5	1.5	1.5	1.5	1.5
Aquadest (mL)	34	34	34	34	34

The oil phase consisted of stearic acid, liquid paraffin, and propyl paraben, while the aqueous phase consisted of methyl paraben, glycerin, TEA, and distilled water. Each phase was heated separately to 70°C. The aqueous phase was then slowly added to the oil phase with continuous stirring until a homogeneous lotion was formed. This method was adapted from standard emulsion preparation procedures (Taylor & Aulton, 2017).

DETERMINATION OF SPF

SPF values were determined using the spectrophotometric method described in a previous study (Dutra et al., 2004). Approximately 0.5 g of each lotion formulation was diluted with ethanol to 25 mL. The absorbance was measured using a UV-Vis spectrophotometer at wavelengths of 290–320 nm with 5 nm intervals. The SPF values were calculated by Equation (2):

$$\text{SPF} = \text{CF} \times \sum_{290}^{320} EE \times I \times Abs \ldots\text{(eq.2)}$$

Where CF is the correction factor (10), EE is the erythemal effect spectrum at wavelength, I is the solar intensity spectrum at wavelength, and Abs is the absorbance of the sample at wavelength.

IRRITATION TEST

Skin irritation testing was performed using the Human 4-Hour Patch Test method (Basketter et al., 2004). Healthy female volunteers aged 17–40 years without a history of skin allergy and not receiving specific medication were included in the study. Female volunteers were selected to obtain a more homogeneous study population and minimize variability in skin responses associated with sex-related physiological differences. All volunteers participated voluntarily and provided written informed consent before enrollment. Participants were informed about the study procedures, potential risks, and their right to withdraw from the study at any time without consequence. The confidentiality of the participant's personal information was maintained throughout the study.

Approximately 0.5 g of each formulation was applied to the inner forearm and covered with a patch. The patch was removed after 4 h. Skin reactions were observed at 0 h after application and at 24, 48, and 72 h after patch removal. During the observation period, respondents were allowed to wash the tested area using water only without soap, detergent, or cosmetic products. Signs of erythema and edema were recorded and calculated by Equation (3):

$$\text{Irritation index} = \frac{(erythema\ score\ for\ 24\ h+48\ h+72\ h)+(edema\ score\ 24\ h+48\ h+72\ h)}{respondent} \quad \ldots\text{(eq.3)}$$

DATA ANALYSIS

All measurements were carried out in triplicate and presented descriptively as mean values. SPF values were classified according to sunscreen protection categories based on SNI number 16-4399-1996.

RESULT AND DISCUSSION

EXTRACTION YIELD OF *Ficus racemosa* L.

The extraction process is a crucial stage in the development of plant-based sunscreen products because both the quantity and quality of extract obtained may influence the concentration of active compounds incorporated into the final formulation. In this study, 120 g of powdered *Ficus racemosa* L. fruit produced 43.967 g of crude ethanolic extract, corresponding to an extraction yield of 36.64%. This extraction yield was lower than reported by Hidayanti et al. (69.1426%), which may be attributed to differences in the extraction solvent used, as their study employed methanol instead of ethanol (Hidayanti et al., 2023). This relatively high yield indicates that the fruit contains substantial amounts of ethanol-soluble constituents. Ethanol is widely recognized as an extraction solvent because it is capable of dissolving a broad range of polar to semi-polar phytochemicals, including flavonoids, tannins, phenolic acids, glycosides, and several other secondary metabolites. These compounds are frequently associated with antioxidant and photoprotective activities, making ethanol a suitable solvent for the extraction of sunscreen-related botanical materials (Nn, 2015). The favorable yield obtained in the present study may also be attributed to the pretreatment process. Drying the plant material before extraction likely reduced moisture content and improved solvent penetration into the cellular matrix, thereby facilitating the release of soluble compounds (Azmir et al., 2013).

In addition, the use of finely powdered material passed through a 200-mesh sieve increased the contact surface area between the sample and the extraction solvent. A smaller particle size generally improves mass transfer and allows the solvent to access intracellular compounds more efficiently. Similar findings have been reported in previous studies showing that particle size reduction can enhance recovery of phytochemicals from plant materials (Azmir et al., 2013). The repeated maceration process also likely contributed to the extraction efficiency observed in this work. Re-maceration using fresh solvent for three cycles may maintain the concentration gradient necessary for continuous diffusion of metabolites from plant tissues into the solvent phase. When extraction is performed only once, equilibrium may be reached before all soluble compounds are released. Therefore, repeated extraction remains a practical and effective approach, particularly in laboratories with limited access to advanced extraction technologies (Nn, 2015).

SUN PROTECTION FACTOR (SPF) OF LOTION FORMULATIONS

The main objective of this study was to evaluate the photoprotective potential of lotion formulations containing ethanolic extract of *Ficus racemosa* L. fruit. SPF values were determined using the UV-Vis spectrophotometric method based on Equation 2, which is commonly employed for preliminary in vitro sunscreen evaluation due to its simplicity, rapidity, and reproducibility. The obtained SPF values showed a clear concentration-dependent trend, where increasing extract concentration resulted in higher SPF values. The SPF values of the lotion formulation are presented in Table 2.

Table 2. The SPF values of the lotion formulation

Formulation	SPF Value	Category
F_0	1.3473	-
F_1	1.5970	No protection
F_2	2.4371	Minimal protection
F_3	4.1191	Moderate protection
F_4	4.3891	Moderate protection

The control formulation (F_0), which did not contain extract, exhibited the lowest SPF value of 1.3473. This result indicates that the lotion base alone provided only minimal UV protection. Such findings are expected because common excipients such as stearic acid, glycerin, liquid paraffin, and aquadest primarily function as emollients, emulsifiers, humectants, and consistency modifiers rather than active UV filters (Taylor & Aulton, 2017). Although some lotion bases may slightly scatter incident light, their protective effect is generally limited. The addition of *Ficus racemosa* L. extract increased the SPF value gradually from F_1 to F_4. Formulations F_1 and F_2 showed SPF values of 1.5970 and 2.4371, respectively, indicating that low extract concentrations were not sufficient to provide meaningful sunscreen protection. However, these values were still higher than those of the control, suggesting that even small amounts of extract contributed measurable UV absorption. A more pronounced increase was observed in formulations F_3 and F_4, which yielded SPF values of 4.1191 and 4.3891, respectively. According to the Indonesian National Standard (SNI) number 16-4399-1996, both formulations fulfilled the minimum SPF requirement and can be categorized as providing moderate protection (Badan Standardisasi Nasional, 1996). These results indicate that concentrations of 0.500 g and 1.000 g extract were more effective in delivering UV-protective constituents into the lotion matrix.

Figure 1. Lotion of *Ficus racemosa* L. (from left to right: F_0, F_1, F_2, F_3, and F_4)

As shown in Figure 1, color intensity increases with extract concentration, accompanied by higher SPF values. This pattern is likely linked to the phytochemical composition of *Ficus racemosa* L. fruit. Previous studies have reported the presence of flavonoids, tannins, and other phenolic compounds in this plant material (Hasnat et al., 2024). These compounds contain aromatic rings and conjugated double-bond systems that absorb ultraviolet radiation, particularly in the UV-B region. In addition, their antioxidant properties may help reduce oxidative stress caused by sunlight exposure (He et al., 2021). Natural phenolic compounds have been widely reported as promising photoprotective agents because they combine direct UV absorption with free-radical scavenging activity (Li et al., 2023). Interestingly, although F_4 showed the highest SPF value, the increase from F_3 to F_4 was relatively small compared with the increments observed at lower concentrations. This finding suggests that the relationship between extract concentration and SPF enhancement was not entirely linear. At higher loading levels, the emulsion system may approach saturation, where additional extract no longer produces proportional increases in UV absorption. This phenomenon may arise from limited solubility or dispersion of extract constituents in the lotion matrix, partial aggregation of extract particles, increased turbidity, or reduced homogeneity of the applied film (Wang et al., 2010). Such behavior has also been observed in other botanical sunscreen formulations, where increasing extract concentration beyond an optimum level may not significantly improve SPF values. Therefore, the selection of an effective concentration should consider not only SPF enhancement but also formulation stability, texture, odor, color, and economic feasibility (Isnaini et al., 2025).

The formulation also contained methyl paraben and propyl paraben as preservatives to maintain microbiological stability during storage and repeated use. This is particularly important for lotion systems because the presence of water can support microbial growth if no preservative system is applied. The combination of methyl paraben and propyl paraben is commonly used because both compounds provide complementary antimicrobial activity, allowing effective preservation at relatively low concentrations (Stroppel et al., 2023). Although parabens have received public attention, international regulatory agencies still permit their use within established safety limits. The Scientific Committee on Consumer Safety concluded that methyl paraben and propyl paraben remain safe for cosmetic use when used at regulated concentrations (Scientific Committee on Consumer Safety (SCCS), 2023). Therefore, their inclusion in the present formulation can be considered scientifically justified to ensure product safety and quality.

The absorbance profile obtained during spectrophotometric analysis indicated stronger absorption at lower wavelengths, particularly within the UV-B range of 290–320 nm. This result is favorable because UV-B radiation is strongly associated with erythema, sunburn, DNA damage, and photocarcinogenesis. However, modern sunscreen products ideally provide broad-spectrum protection against both UV-B and UV-A radiation (Chavda et al., 2023). Therefore, future studies should also evaluate UV-A protection parameters such as critical wavelength, UVA/UVB ratio, or in vivo broad-spectrum performance. When compared with several natural sunscreen studies reported in the literature, the SPF values obtained in the present study can be considered moderate. Nevertheless, direct comparison between studies should be interpreted carefully because SPF values are highly influenced by extraction solvent, extract concentration, dosage applied, vehicle composition, and analytical method (Wang et al., 2010). Importantly, plant extracts are not always intended to fully replace synthetic filters, but may serve as multifunctional ingredients that combine mild UV protection with antioxidant, anti-inflammatory, and consumer-friendly natural attributes (Saewan & Jimtaisong, 2015). From a practical perspective, formulations F_3 and F_4 were identified as the most promising sunscreen candidates. Both met the minimum SPF requirement while maintaining acceptable topical safety. Among them, F_3 may represent the more efficient option because it required only half the extract amount used in F_4 while producing a relatively similar SPF value. This balance between efficacy and material efficiency may be advantageous for future product scale-up.

SKIN IRRITATION TEST

Besides efficacy, safety is an essential aspect in the development of sunscreen products because such formulations are commonly applied repeatedly and often over large skin areas. In the present study, irritation testing was conducted using the Human 4-Hour Patch Test on 15 healthy volunteers aged 17–40 years. Skin responses were evaluated based on the presence of erythema and edema after exposure to each formulation (Basketter et al., 2004). The results demonstrated that all tested formulations produced a score of zero (0) for both erythema and edema throughout the observation period. No visible redness, swelling, itching, or discomfort was reported by any volunteer. Representative visual images of the test area are presented in Figure 2.

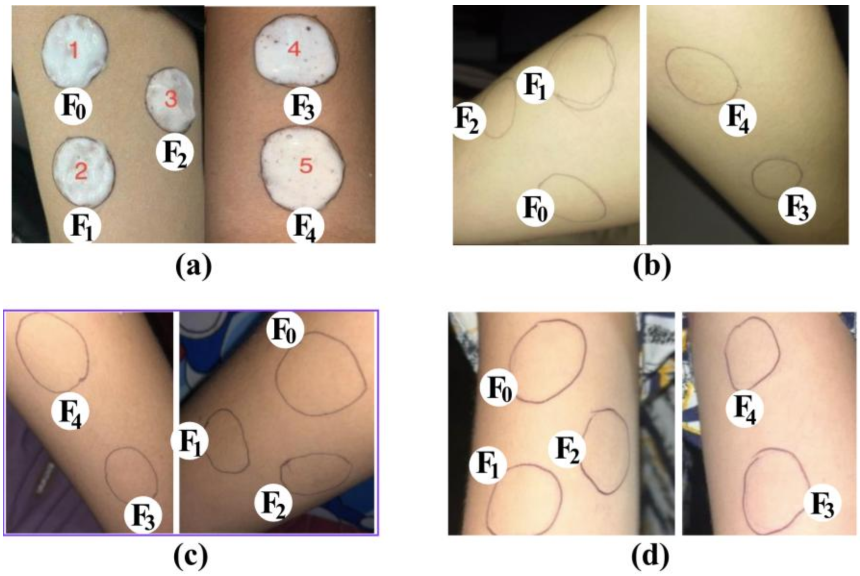

Figure 2. Representative of the skin irritation test area at (a) baseline, (b) 24 h after patch removal, (c) 48 h after patch removal, and (d) 74 h after patch removal.

These findings indicate that the lotion formulations were well tolerated and did not induce acute skin irritation under the conditions of this study. The favorable tolerability observed may be related to the physicochemical characteristics of the formulations reported in the previous study (Suryani et al., 2024), where the lotion base showed acceptable pH, homogeneity, spreadability, and stability. Appropriate pH is particularly important because excessively acidic products or alkaline products may disrupt the skin barrier and trigger irritation responses. A homogeneous and stable emulsion system may also help distribute active compounds more evenly across the skin surface, thereby reducing the risk of localized irritation (Taylor & Aulton, 2017). Another possible explanation for the absence of irritation is the presence of antioxidant phytochemicals in the extract.

Flavonoids and phenolic compounds have been widely reported to exhibit anti-inflammatory and protective effects against oxidative stress (Li et al., 2023). Although these mechanisms were not directly investigated in the present study, they may contribute to the overall skin compatibility of the formulation. Despite these encouraging results, several limitations should be acknowledged. The patch test was conducted on a relatively small number of healthy volunteers and reflected short-term exposure only. The study did not evaluate repeated-use irritation, sensitization potential, photoallergy, or reactions in individuals with sensitive skin conditions. Therefore, broader dermatological evaluation would be valuable before commercialization (Basketter et al., 2004).

CONCLUSION

This study demonstrated that the ethanolic extract of *Ficus racemosa L.* has potential as a natural sunscreen ingredient in lotion formulations, as increasing extract concentration improved SPF values, with formulations F_3 and F_4 achieving moderate protection (SPF 4.1191 and 4.3891, respectively) and meeting the minimum sunscreen standards. All formulations also showed no signs of skin irritation, indicating good preliminary topical safety. Among the tested formulations, F_3 demonstrated comparable SPF performance to F_4 while requiring a lower extract concentration. These findings highlight the opportunity to utilize *Ficus racemosa L.* as a locally sourced botanical material for sunscreen development. However, this study was limited to in vitro SPF evaluation and short-term irritation testing; therefore, further research on long-term stability, microbiological quality, broad-spectrum UV protection, and in vivo efficacy is still required.

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